AEROSPACE MATERIAL SPECIFICATION

AMS2759™/6	REV. D

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Superseding AMS2759/6C

Gaseous Nitriding of Steel Parts, Controlled by Ammonia Dissociation

RATIONALE

AMS2759/6D results from a Five-Year Review and update of this specification with changes to Ordering Information, Purpose (see 1.1), Application (see 1.2.2), Definitions (see 2.4), Measurement (see 3.2.2.1), Prior Heat Treatment (see 3.4.1), Stress Relieving (see 3.4.2), Cleaning (see 3.4.3), Masking (see 3.4.4), Visual Inspection (see 3.4.5), Nitriding Temperature Range (see 3.4.7.2), Cooling (see 3.4.8), Hardness at effective case depth (see Table 1), Case Hardness (see 3.6.2), Minimum case hardness requirements (see Table 2), Core Hardness (see 3.6.4), Case Microstructure (see 3.6.5), Acceptance Tests (see 4.2.1), Preproduction Tests (see 4.2.3), Process Control Specimens (see 4.3.1), Specimen Description (see 4.3.2), Inspection of Masking (see 4.3.5), Core Hardness (see 4.3.6), and Resampling and Retesting (see 4.5.1).

NOTICE

ORDERING INFORMATION: In addition to that listed in AMS2759, the purchaser shall supply the following information to the nitriding processor.

- AMS2759/6D
- Engineering drawing or detailed operation information
- Critical dimensions information as applicable (see 3.4.2)
- Class of white layer depth (thickness) (see 1.3)
- Areas to be nitrided, areas to be masked, areas to be optional (see 3.4.3)
- Areas to be ground after nitride, if applicable (see 3.4.3)
- Prior heat treatment information, including actual tempering/aging temperature and hardness
- Any prior stress relieving performed, including specifics and if stress relief is to be performed by the nitride processor (see 3.4.2)
- Total case depth (see 3.6.1.1)
- Effective case depth, if applicable (see 3.6.1.2)

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Tel: +1 724-776-4970 (outside USA)
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Email: CustomerService@sae.org
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- Case (surface) hardness, if different than in Table 2 (see 3.6.2)
- White layer removal requirements, if applicable (see 3.5.2)
- Post-nitriding core hardness, if specified (see 3.6.4)
- If parts are to be used for testing (see 4.3.1)
- Grind stock allowances to be removed in subsequent polishing/grinding (see 3.5.2.1)

1. SCOPE

1.1 Purpose

This document specifies the procedure and requirements for gas nitriding steel parts by the use of raw or dissociated ammonia.

1.2 Application

1.2.1 The nitriding process described herein has been used typically for producing a wear-resistant and fatigue-resistant surface on steel parts, but usage is not limited to such applications. This process only applies to gas nitriding. Other processes, such as salt bath nitriding per AMS2753, ion nitriding per AMS2759/8, automated gas nitriding controlled by nitriding potential per AMS2759/10, automated gas nitrocarburizing by potential per AMS2759/12, and gas nitrocarburizing per AMS2757, are not included.

1.2.2 AMS 2759/10 automatic gas nitriding meets the requirements of this specification and is an acceptable alternate.

1.3 Classification

Processes covered by this specification are classified as follows:

Class 1: Two-stage nitriding with maximum applied white layer of 0.0005 inch (12.7 µm).

Class 2: One-stage nitriding with a maximum applied white layer of 0.001 inch (25.4 µm).

If no class is specified, either Class 1 or Class 2 may be provided.

2. APPLICABLE DOCUMENTS

In addition to those listed in AMS2759, 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 processor 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.

AMS2418 Plating, Copper

AMS2429 Plating, Bronze, Nitriding Stop-off, 90Cu - 10Sn

AMS2750 Pyrometry

AMS2753 Liquid Salt Bath Ferritic Nitrocarburizing Non-Cyanide Bath

AMS2757 Gaseous Nitrocarburizing

AMS2759 Heat Treatment of Steel Parts, General Requirements

ARP1820 Chord Method of Evaluating Surface Microstructural Characteristics

AS7766 Terms Used in Aerospace Metals Specifications

2.2 ASM International Publications

Available from ASM International, 9639 Kinsman Road, Materials Park, OH 44073-002, Tel: 440-671-3800, www.asminternational.org.

ASM Metals Handbook

2.3 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 E140 Standard Hardness Conversion Tables for Metals

2.4 Definitions

Terms used in AMS2759/6 are defined in AMS2759, AS7766, and as follows:

2.4.1 WHITE LAYER

The white layer, also known as the compound zone, is the external, non-etching portion of nitrided layer composed of compact epsilon or gamma prime nitrides or a combination thereof.

3. TECHNICAL REQUIREMENTS

3.1 Pyrometry

Shall be in accordance with AMS2750.

3.2 Furnace Equipment

Shall be in accordance with AMS2759. Nitriding furnaces shall be Class 3 or better.

3.2.1 Nitriding Environment

Equipment shall be in place for introducing ammonia gas into the furnace at a controlled rate. A separate system for ammonia dissociation is recommended.

3.2.2 Atmosphere Control

Equipment shall be in place to measure and maintain the dissociation of the process atmosphere going through the retort or furnace throughout the nitriding cycle.

3.2.2.1 Measurement

Equipment used for measuring the gas dissociation shall be at the exit of the retort or furnace. Water absorption techniques, such as the use of burettes, are acceptable. Infrared analysis or in-situ probes shall be checked annually in accordance with manufacturers' recommendations.

3.3 Auxiliary Equipment

Shall be in accordance with AMS2759.

3.4 Procedure

3.4.1 Prior Heat Treatment

3.4.1.1 If any specified heat treatment has already been performed, information regarding that heat treatment shall have been provided. Heat-treatment certifications are recommended but not required. The hardness of heat-treated parts should be verified by the processor prior to nitriding by testing at least one part in accordance with ASTM E18. Part hardness may be determined on a surface of the part where no nitriding is required (such as on a surface that is to be masked) or may be determined at a designated position on a cross section of a specimen or part.

3.4.1.2 If any specified heat treatment is to be performed by the nitriding processor, it shall be performed prior to nitriding. If a heat treatment is specified but a control document is not referred to, then the heat treatment shall be controlled and tested in accordance with AMS2759 and applicable AMS2759 slash specifications.

3.4.2 Stress Relieving

Unless otherwise specified, parts that have critical dimensions to be held through nitriding and that have been rough ground, straightened, machined, or otherwise mechanically worked after heat treatment shall be stress relieved prior to nitriding in accordance with AMS2759/11. After stress relieving and prior to nitriding, it is permissible for surfaces to be mechanically or chemically cleaned.

3.4.3 Cleaning

Parts shall be cleaned in accordance with AMS2759 such that sufficient and uniform nitriding is able to take place. Care shall be exercised after cleaning to prevent recontamination. After stress relieving and prior to nitriding, it is permissible for surfaces to be mechanically or chemically cleaned.

3.4.4 Masking

Areas not allowed to be nitrided shall be masked. Alternatively, parts may be nitrided on all surfaces and the case ground off the surfaces that are not allowed to be nitrided.

3.4.4.1 Prohibition

Nitriding is prohibited on surfaces not designated to be nitrided except where optional nitriding is permitted.

3.4.4.2 Maskant

Shall be fine grained copper plate, not less than 0.001 inch (26 µm) in thickness, applied in accordance with AMS2418 or bronze plate, not less than 0.0005 inch (13 µm) in thickness, applied in accordance with AMS2429. Paints, pastes, or mechanical methods may be used if acceptable to the cognizant engineering organization. Additionally, maskants shall be checked visually for evidence of blistering after nitriding but before subsequent stripping and etching.

3.4.5 Visual Inspection

Masked or plated parts shall be visually inspected prior to and after nitriding. Parts exhibiting blistering, peeling, or porosity in the masking before or after nitriding shall be rejected (see 8.7).

3.4.6 Racking

Rack to prevent distortion and to ensure free circulation of the nitriding gas to all surfaces. Test specimens, or parts to be destructively evaluated, shall be placed in the working zone in approximately the same location or locations as the parts they represent.

3.4.7 Nitriding

3.4.7.1 Dissociation

For Class 2 and the first stage of Class 1 (approximately 20% of the total nitriding time), it is recommended that the ammonia gas dissociation set point be within the range of 12 to 35%. For the second stage of Class 1, it is recommended that the ammonia dissociation set point be within the range of 55 to 88%.

3.4.7.2 Nitriding Temperature Range

The recommended nitriding temperature range is 915 to 1095 °F (491 to 591 °C). Lower temperatures can be used when needed. The nitriding temperature shall not exceed 1200 °F (649 °C). The nitriding temperature shall not be higher than 50 °F (28 °C) below the final tempering or processing temperature unless the part hardness can be verified on an actual or representative part. The nitriding temperature shall not exceed the tempering or aging temperature.

3.4.7.3 Nitriding Procedure

The load shall be held at nitriding temperature(s) in an atmosphere in accordance with 3.4.7.1 for sufficient time to produce the specified case depth.

3.4.8 Cooling

The load shall be purged and cooled from the nitriding temperature in a suitable protective atmosphere to 300 °F (149 °C) or below.

3.5 Post-Nitriding Operations

3.5.1 Maskant Stripping

When required, stripping of maskant shall be accomplished by use of an appropriate stripping solution that shall not pit or etch the part. If an electrolytic stripping solution is used, parts shall be embrittlement relieved in accordance with 3.5.3.

3.5.2 Removal of White Layer

When white layer is partially or totally restricted, the white layer shall be removed to meet the requirements of 3.6.3 by lapping, honing, grinding, or etching with maximum stock removal of 0.002 inch (0.05 mm). If etching is used, parts shall be embrittlement relieved after etching in accordance with 3.5.3.

3.5.2.1 Limitation on Metal Removal

When any metal removal is performed, it shall not reduce the effective case depth or case hardness to below specified requirements.

3.5.3 Embrittlement Relief

Pickled, plated, etched to remove white layer, or electrolytically cleaned or stripped parts shall be baked to remove hydrogen as specified in AMS2759/9. Where pickling or electrolytic cleaning is performed as an integral part of a plating operation, baking is not required after each process but shall be performed following the final process provided not more than 4 hours elapse between such operations.

3.6 Properties

3.6.1 Case Depth

The depth shall meet the requirements of the engineering drawing. If the engineering drawing and/or purchase order specifies a case depth but does not specifically state that it is to be an effective case depth, then total case depth shall apply. In cases where the engineering drawing or purchase order specifies post-nitride surface removal (see Ordering Information), the reported case depth shall include the amount to be removed.

3.6.1.1 Total Case Depth

The total case depth shall be the depth of the continuous etching subsurface zone, determined metallographically from a section of the as-nitrided part or a control specimen prior to machining, or may be determined by a microindentation hardness traverse conducted in accordance with ASTM E384. On those alloys which do not respond by darker etching, the total case depth shall be the depth below the surface at which the hardness is 50 HK or 50 HV higher than the core below the nitride case as determined by a Knoop or a Vickers hardness traverse, respectively. The average of a minimum of three hardness readings taken at a minimum distance of two times the case depth shall be used to determine the core hardness below the case.

3.6.1.2 Effective Case Depth

When required (see Ordering Information), the effective case depth shall be as specified. It shall be the as nitrided case depth at which the values specified in Table 1, converted from microindentation hardness, are obtained by performing a hardness traverse in accordance with ASTM E384. In cases where the engineering drawing or purchase order specifies post-nitride surface removal (see Ordering Information), the reported effective case depth shall include the amount to be removed.

Table 1 - Hardness at effective case depth

Specification	Alloy	Hardness HRC or Equivalent (see 8.11)
AMS6470, AMS6471, AMS6472	Nitralloy 135 Mod	50
N/A	Nitralloy EZ	50
AMS6475	Nitralloy N	50
AMS6382, AMS6414, AMS6415(1)	4140, 4340	40
AMS6431, AMS6438	D6AC	50
AMS6485, AMS6487, AMS6488, AMS6408	H11, H13	60
AMS6496, AMS6497, AMS6498	GKP, GKPW, GKPYW	50
AMS6481	GKHYW	50
Other alloys		As specified

(1) For alloy steels heat treated to a core hardness of 36 to 40 HRC or greater, effective case depth shall be determined by a microhardness reading of 50 Knoop or Vickers above the core hardness.

3.6.2 Case (Surface) Hardness

The minimum case hardness shall be as stated in Table 2, determined in accordance with ASTM E18 or ASTM E384 after any material is to be removed. In case of dispute, the surface Rockwell superficial hardness shall govern provided the depth and hardness is appropriate to support the hardness value. If not, then the microindentation hardness at a depth of 0.002 inch (51 µm) from the surface shall take precedence. If material is to be removed as specified in the ordering information, the microindentation hardness values shall be taken at 0.002 inch (51 µm) from the predicted finished surface.

Table 2 - Minimum case hardness requirements

Alloy	Hardness (HR15N) or Equivalent (see 8.11)
Nitralloy 135 modified	92.5
Nitralloy EZ	92.5
Nitralloy N	92.5
AISI 4140, AISI 4340	85.5
D6AC	85.5
H11, H13	92.1
GKP, GKPW, GKPYW	90.3
GKHYW	90.3
Other alloys	As specified

3.6.3 White Layer

When white layer is permitted, its maximum applied thickness shall be 0.0005 inch (12.7 µm) for Class 1 and 0.001 inch (25.4 µm) for Class 2 as determined by metallographic examination in accordance with 4.3.3. White layer may be limited or totally restricted per the engineering drawing in some or all areas regardless of the nitriding class and shall be treated in accordance with 3.5.2.

3.6.4 Core Hardness

If specified, the post-nitriding core hardness shall meet requirements. Post-nitriding core hardness shall be the hardness at a minimum of two times the specified case depth. It shall be the average of at least three hardness readings taken in accordance with ASTM E384. Core hardness readings can also be taken in accordance with ASTM E18.

3.6.5 Case Microstructure

The finished case in low alloy steels shall exhibit a uniform distribution of nitrides diminishing gradually from the surface to the core. Corrosion-resistant steels and highly alloyed steels (e.g., tool steels) may exhibit one or two metallographically distinct zones, which may end abruptly. There shall be no evidence of a continuous nitride network in grain boundaries. Nitride networks are permissible at corners and sharp edges provided it does not exceed a depth of two grain boundaries from the outside surface or it does not exceed 20% of the case depth, including the amount to be removed when applicable. Cracking at the surface or in the nitride layer is not permitted (see 8.12).

4. QUALITY ASSURANCE PROVISIONS

The responsibility for inspection, classification of tests, sampling and testing, approval, records, record retention, and report/certification shall be in accordance with AMS2759 and as follows:

4.1 Responsibility for Inspection

Where parts are required for destructive tests, these shall be provided by the purchaser.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Inspection of masking (see 3.4.5), case depth (see 3.6.1), case hardness (see 3.6.2), white layer (see 3.6.3), core hardness, if specified (see 3.6.4), and case microstructure (see 3.6.5) are acceptance tests and shall be performed on each lot of parts.

4.2.2 Periodic Tests

Shall be in accordance with AMS2759.

4.2.3 Preproduction Tests

Shall be in accordance with AMS2759.

4.3 Sampling and Testing

A lot shall be all parts of the same alloy and part number, heat treated to the same property requirements, nitrided in the same furnace at the same time, and presented for the processor’s inspection at one time.

4.3.1 Process Control Specimens

Each lot of parts nitrided in each furnace load shall be accompanied by at least one process control specimen of the same alloy. Actual parts, or sections of parts, produced from the same machining and heat treating lot as the parts to be nitride are preferred. When test specimens are used, they shall conform to 4.3.2. Parts shall be used for testing only when specified by the purchaser. Specimens shall be identified for correlation with the furnace load lots and the parts. Specimens or test parts shall have been hardened by the same treatment as the parts and shall have been appropriately masked, if the parts are masked, along with the parts.

4.3.2 Specimen Description

Specimens shall be of the same alloy and heat-treatment condition as the actual parts, having a thickness not less than 0.125 inch (3.2 mm). Alternatively, parts may be used in lieu of a specimen (see 4.3.1). Specimen preparation shall be done in the same manner as the parts they represent.

4.3.3 Metallographic Examination

Shall be made on polished and etched specimens. Specimens may be plated for edge retention prior to mounting. If plating is used, it shall be by a method that does not remove material from the surface of the specimen. Visual examination for white layer or case microstructure shall be performed at a minimum of 400X magnification. In case of dispute, the chord method, described in ARP1820, or equivalent, may be used to assess the surface features (e.g., white layer) of the case. If a part is used in lieu of a specimen, the surface should be sliced at an angle to magnify the surface by a factor of at least three.

4.3.4 Surface Hardness

Unless otherwise specified, a minimum of 5% of each lot of nitrided parts shall be tested for surface hardness after completion of white layer removal. This is in addition to hardness testing of control test specimens.

4.3.5 Inspection of Masking

Sampling for visual inspection of masking (see 3.4.5) shall be 100% of the parts in each lot.

4.3.6 Core Hardness

If specified and when masking has not been used, a part or the process control specimen shall be tested to determine core hardness. If specified and when masking has been used, the masked control specimen(s) shall be tested to determine core hardness by removing the maskant and checking on the surface or by using microhardness and checking at 0.005-inch (0.127-mm) depth below the maskant layer.

4.4 Reports

In addition to that required in AMS2759, the report shall show the results of tests for core hardness, microstructure, white layer, as-nitrided case depth, and case hardness and state that nitriding conformed to the other specified requirements. When post-nitride stock removal is specified, the microindentation hardness traverse data (see 3.6.1.2) shall be reported along with a statement that the reported effective case depth includes the amount to be removed.

4.4.1 If finish machining is performed by the nitride processor, the report shall show maximum and minimum stock removal, effective case depth, depth of white layer if present, and case hardness after machining.

4.5 Resampling and Retesting

If any specimen used in the above tests fails to meet the specified requirements, disposition of the heat-treated parts may be based on the results of testing a production part. Except as permitted in 4.4.1, failure of any retest specimen or part to meet the specified requirements shall be cause for rejection of the parts represented. Results of all tests shall be reported.