



AEROSPACE MATERIAL SPECIFICATION

AMS6409™**REV. F**Issued 1987-01
Revised 2021-09

Superseding AMS6409F

Steel, Bars, Forgings, Mechanical Tubing and Forging Stock
0.80Cr - 1.8Ni - 0.25Mo (0.38 - 0.43C) (SAE 4340)
Special Aircraft Quality Cleanliness
Normalized and Tempered
(Composition similar to UNS G43406)

RATIONALE

AMS6409F results from a Five-Year Review and update of this specification that updates the title, revises composition (3.1), condition (3.2.2), updates note on Table 2, updates macrostructure (3.3.1.1, 3.3.1.2, 8.9), adds specimen heat treatment (3.3.3), updates decarburization (3.3.4.1, 3.3.4.5), adds strain rate to tensile testing (3.3.5.1), prohibits unauthorized exceptions (3.6, 4.4.5, 5.2.1, 8.8), acknowledges periodic testing (4.2.1, 4.4.4), allows prior revisions (8.7) and is the result of a Five-Year Review and update of the specification.

1. SCOPE

1.1 Form

This specification covers a low-alloy steel in the form of bars, forgings, mechanical tubing, and forging stock.

1.2 Application

These products have been used typically for parts required to meet stringent magnetic particle inspection criteria, having sections 3.5 inches (89 mm) and under in nominal thickness at time of heat treatment, and requiring a through-hardening steel capable of developing a minimum hardness of 40 HRC when properly hardened and tempered and also for parts of greater thickness, but requiring proportionately lower hardness, but usage is not limited to such applications.

1.2.1 Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking after heat treatment; ARP 1110 recommends practices to minimize such conditions.

1.2.2 These products are not recommended for use in parts heat treated to a hardness greater than 46 HRC (ultimate tensile strength over 220 ksi (1517 MPa)) or where the high transverse properties of remelted steel are required (see 8.2).

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.

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For more information on this standard, visit

<https://www.sae.org/standards/content/AMS6409F/>

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.

AMS2251	Tolerances Low-Alloy Steel Bars
AMS2253	Tolerances Carbon and Alloy Steel Tubing
AMS2259	Chemical Check Analysis Limits Wrought Low-Alloy and Carbon Steels
AMS2304	Steel Cleanliness, Special Aircraft-Quality Magnetic Particle Inspection Procedure
AMS2370	Quality Assurance Sampling and Testing Carbon and Low-Alloy Steel Wrought Products and Forging Stock
AMS2372	Quality Assurance Sampling and Testing Carbon and Low-Alloy Steel Forgings
AMS2759/1	Heat Treatment of Carbon and Low-Alloy Steel Parts Minimum Tensile Strength Below 220 ksi (1517 MPa)
AMS2761	Heat Treatment of Steel Raw Materials
AMS2806	Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS2808	Identification Forgings
AS1182	Standard Stock Removal Allowance Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing
ARP1110	Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications

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 A255	Determining Hardenability of Steel
ASTM A370	Mechanical Testing of Steel Products
ASTM A751	Chemical Analysis of Steel Products
ASTM E112	Determining Average Grain Size
ASTM E140	Hardness Conversion Tables for Metals, Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness
ASTM E381	Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
ASTM E1077	Estimating the Depth of Decarburization of Steel Specimens

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined in accordance with ASTM A751 or by other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	Min	Max
Carbon	0.38	0.43
Manganese	0.65	0.85
Silicon	0.15	0.35
Phosphorus	--	0.015
Sulfur	--	0.008
Chromium	0.70	0.90
Nickel	1.65	2.00
Molybdenum	0.20	0.30
Copper	--	0.35

3.1.1 Aluminum, vanadium, and columbium are optional grain refining elements and need not be determined or reported unless used to satisfy the average grain size requirements of 3.3.2.2.

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Condition

The product shall be supplied in the following condition; hardness shall be determined in accordance with ASTM A370:

3.2.1 Bars

Normalized at 1650 °F ± 25 °F (899 °C ± 14 °C) and tempered, having hardness at mid-radius not higher than 322 HBW, or equivalent (see 8.3). Bars shall have a turned, ground, polished, or burnished surface; surface hardness shall be not more than 3 points HRC harder than mid-radius hardness. Bars with a mid-radius hardness less than 20 HRC shall not have a surface hardness greater than that of the mid-radius hardness by the equivalent of 20 HBW.

3.2.1.1 When hot finished or cold drawn bars are specified, the surface hardness shall be not more than 3 points HRC harder than the mid-radius hardness as in 3.2.1. Bars with a mid-radius hardness less than 20 HRC shall not have a surface hardness greater than that of the mid-radius hardness by the equivalent of 20 HBW.

3.2.1.2 Bar shall not be cut from plate (also see 4.4.2).

3.2.2 Forgings

Normalized and tempered in accordance with AMS2761 having hardness not higher than 322 HBW, or equivalent (see 8.3).

3.2.3 Mechanical Tubing

Normalized and tempered having hardness not higher than 322 HBW, or equivalent (see 8.3). Tubing 1.0 inch (25 mm) and under in nominal OD shall be cold reduced; larger sizes shall be hot rolled.

3.2.4 Forging Stock

As ordered by the forging manufacturer.

3.3 Properties

The product shall conform to the following requirements; hardness testing shall be performed in accordance with ASTM A370:

3.3.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, tube rounds (solid, not hollow), and forging stock, etched in hot hydrochloric acid in accordance with ASTM E381, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM E381 shown in Table 2.

Table 2 - Macrostructure limits

Cross-Section Area Square Inches	Cross-Sectional Area Square Centimeters	Macrographs
Up to 36, incl	Up to 232, incl	S2 - R1 - C2
Over 36 to 100, incl	Over 232 to 645, incl	S2 - R2 - C2
Over 100 to 133, incl	Over 645 to 858, incl	S2 - R2 - C3
Over 133	Over 858	Note 1

Note 1: Limits for larger sizes shall be agreed upon by purchaser and producer.

3.3.1.1 Macrostructure examination is not required for bored/hollow forgings (including ring forgings) and mechanical tubing that is produced directly from ingots or large blooms unless otherwise agreed upon by purchaser and producer (see 8.9).

3.3.1.2 If mechanical tubing is produced directly from ingots or large blooms, transverse sections may be taken from the tubing. Macrostructure standards for such tubes shall be as agreed upon by purchaser and producer (see 8.9).

3.3.2 Average Grain Size of Bars, Forgings, and Tubing

Average grain size shall be determined by either 3.3.2.1 or 3.3.2.2.

3.3.2.1 Shall be ASTM No. 5 or finer, determined in accordance with ASTM E112.

3.3.2.2 The product of a heat shall be considered to have an ASTM No. 5 or finer austenitic grain size if one or more of the following are determined by heat analysis (see 8.6):

3.3.2.2.1 A total aluminum content of 0.020 to 0.050%.

3.3.2.2.2 An acid soluble aluminum content of 0.015 to 0.050%.

3.3.2.2.3 A vanadium content of 0.02 to 0.08%.

3.3.2.2.4 A columbium content of 0.02 to 0.05%.

3.3.3 Hardenability of Each Heat

Shall be J 12/16 inch (J19 mm) = 53 HRC, minimum, and J 20/16 inch (J32 mm) = 50 HRC, minimum, determined on the standard end-quench test specimen in accordance with ASTM A255 except that the steel shall be normalized at 1600 °F ± 10 °F (871 °C ± 6 °C) and the specimen austenitized at 1550 °F ± 10 °F (843 °C ± 6 °C). Cast specimens do not need to be normalized.

3.3.4 Decarburization

3.3.4.1 Bars and tubing ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces.

- 3.3.4.2 Allowable decarburization of bars, billets, and tube rounds ordered for redrawing or forging or to specified microstructural requirements shall be as agreed upon by purchaser and producer.
- 3.3.4.3 Decarburization of bars, for which 3.3.4.1 or 3.3.4.2 are not applicable, shall not exceed the values shown in Table 3.

Table 3A - Maximum total depth of decarburization, inch/pound units

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inches
Up to 0.375, incl	0.010
Over 0.375 to 0.500, incl	0.012
Over 0.500 to 0.625, incl	0.014
Over 0.625 to 1.000, incl	0.017
Over 1.000 to 1.500, incl	0.020
Over 1.500 to 2.000, incl	0.025
Over 2.000 to 2.500, incl	0.030
Over 2.500 to 3.000, incl	0.035
Over 3.000 to 4.000, incl	0.045

Table 3B - Maximum total depth of decarburization, SI units

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
Up to 9.50, incl	0.25
Over 9.50 to 12.50, incl	0.30
Over 12.50 to 15.65, incl	0.36
Over 15.65 to 25.00, incl	0.43
Over 25.00 to 37.50, incl	0.51
Over 37.50 to 50.00, incl	0.64
Over 50.00 to 62.50, incl	0.76
Over 62.50 to 75.00, incl	0.89
Over 75.00 to 100.00, incl	1.14

- 3.3.4.4 Decarburization of tubing, for which 3.3.4.1 or 3.3.4.2 are not applicable, shall not exceed the values shown in Table 4.

Table 4A - Maximum total depth of decarburization, inch/pound units

Nominal Wall Thickness Inches	Total Depth ID Inches	Total Depth OD Inches
Up to 0.109, incl	0.008	0.015
Over 0.109 to 0.203, incl	0.010	0.020
Over 0.203 to 0.400, incl	0.012	0.025
Over 0.400 to 0.600, incl	0.015	0.030
Over 0.600 to 1.000, incl	0.017	0.035
Over 1.000	0.020	0.040

Table 4B - Maximum total depth of decarburization, SI units

Nominal Wall Thickness Millimeters	Total Depth ID Millimeters	Total Depth OD Millimeters
Up to 2.75, incl	0.20	0.38
Over 2.75 to 5.00, incl	0.25	0.51
Over 5.00 to 10.00, incl	0.30	0.64
Over 10.00 to 15.00, incl	0.35	0.76
Over 15.00 to 25.00, incl	0.40	0.89
Over 25.00	0.50	1.02

3.3.4.5 Decarburization shall be evaluated by one of the two methods of 3.3.4.5.1 or 3.3.4.5.2.

3.3.4.5.1 Metallographic (Microscopic) Method

A cross section taken perpendicular to the surface shall be prepared in accordance with ASTM E1077, etched, and examined metallographically at a magnification not to exceed 100X. The product shall not show a layer of complete decarburization (ferrite) or partial decarburization exceeding the limits of Tables 3 or 4.

3.3.4.5.2 Hardness Traverse (Microindentation) Method

The total depth of decarburization shall be determined by a traverse method using microindentation hardness testing in accordance with ASTM E1077. Samples shall be hardened, but untempered and protected during heat treatment to prevent changes in surface carbon content. Measurements shall be far enough away from any adjacent surface to be uninfluenced by any decarburization on the adjacent surface. Acceptance shall be as listed in Tables 3 or 4.

3.3.4.6 When determining the depth of decarburization, it is permissible to disregard local areas provided the decarburization of such areas does not exceed the above limits by more than 0.005 inch (0.13 mm) and the width is 0.065 inch (1.65 mm) or less.

3.3.4.7 In case of dispute, the depth of decarburization determined using the microindentation hardness traverse method shall govern.

3.3.5 Tensile Properties

After being heat treated in accordance with AMS2761 or AMS2759/1 at the producer's option, to an ultimate tensile strength range of 180 to 200 ksi (1241 to 1379 MPa), product shall have a transverse reduction of area not lower than 15% (see 1.2.2).

3.3.5.1 Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ± 0.002 in/in/min (± 0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 and 0.5 in/in (0.05 and 0.5 mm/mm) of the length of the reduced section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 and 0.5 in/in/min (0.05 and 0.5 mm/mm/min).

3.4 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.4.1 Steel shall be special aircraft-quality conforming to AMS2304.

3.4.2 Bars and mechanical tubing shall be free from seams, laps, tears, and cracks after removal of the standard stock removal allowance in accordance with AS1182.

3.4.3 Grain flow of die forgings, except in areas that contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.5 Tolerances

3.5.1 Bars

In accordance with AMS2251.

3.5.2 Mechanical Tubing

In accordance with AMS2253.

3.6 Exceptions

Any exception shall be authorized by purchaser and reported as in 4.4.5.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), condition (3.2), macrostructure (3.3.1), average grain size (3.3.2), hardenability (3.3.3), decarburization (3.3.4), frequency-severity cleanliness rating (3.4.1), and tolerances (3.5) are acceptance tests and shall be performed on each heat or lot as applicable. If grain refining elements (3.3.2.2) are not present, the ASTM E112 grain size test (3.3.2.1) shall be conducted on each lot. If process qualification in accordance with AMS2304 has been met, the frequency-severity cleanliness rating shall be conducted on a periodic basis as defined in AMS2304.

4.2.2 Periodic Tests

If grain refining elements (3.3.2.2) are present, the ASTM E112 grain size test (3.3.2.1) shall be conducted on a periodic basis and shall be performed at a frequency selected by the producer (not to exceed one year) unless frequency of testing is specified by purchaser. Tensile properties after heat treatment (3.3.5) and grain flow of die forgings (3.4.3) are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

4.3.1 Bars, Mechanical Tubing, and Forging Stock

In accordance with AMS2370.

4.3.2 Forgings

In accordance with AMS2372.

4.4 Reports

- 4.4.1 The producer of bars, forgings, and tubing shall furnish with each shipment a report showing the producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), results of tests for composition, condition, macrostructure, hardenability, and frequency-severity rating of each heat, and for the average grain size if measured of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS6409F, product form and size (and/or part number, if applicable), and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included. If the grain size requirement of 3.3.1.2 is met by the aluminum, vanadium and/or columbium content, the aluminum, vanadium and/or columbium content shall be reported and a statement that the chemistry satisfies the grain size requirement shall be included.
- 4.4.2 If the ship size/shape is cut from a larger cross section, report the nominal metallurgically worked size (also see 3.2.1).
- 4.4.3 The producer of forging stock shall furnish with each shipment a report showing the producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), results of tests for composition, macrostructure, hardenability, and the frequency-severity cleanliness rating of each heat (see 4.4.4) and the results of any additional property requirements imposed by 8.9. This report shall include the purchase order number, heat number, AMS6409F, size, and quantity.

4.4.4 Reduced Testing

If the producer has qualified for periodic testing for frequency-severity cleanliness rating in accordance with AMS2304, then the frequency severity cleanliness rating is not required to be reported for each shipment. In this circumstance the report shall read, "Process qualification in accordance with AMS2304 has been completed."

- 4.4.5 When material produced to this specification has exceptions authorized by purchaser taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS6409F(EXC) because of the following exceptions:" and the specific exceptions shall be listed (also see 5.2.1).

4.5 Resampling and Retesting

4.5.1 Bars, Mechanical Tubing, and Forging Stock

In accordance with AMS2370 except that resampling for cleanliness shall conform to 4.5.3.

4.5.2 Forgings

In accordance with AMS2372 except that resampling for cleanliness shall conform to 4.5.3.

4.5.3 Cleanliness

If any specimen fails to meet the specified frequency-severity cleanliness requirements, the entire heat shall be rejected or resampling and retesting shall be performed as follows:

4.5.3.1 Nonconforming Ingot(s)

Reject or take additional discard, resample, and retest.

4.5.3.2 Ingot(s) Not Originally Sampled

Sample and test material from the respective nonconforming position(s), i.e., top or bottom, of two additional ingots for each nonconforming ingot. The ingots selected for additional samples shall be from locations in the pouring plate pattern closest to the nonconforming ingot(s).

4.5.3.3 If the nonconforming ingot(s) fail(s) the retest, repeat 4.5.3.1.