AEROSPACE MATERIAL SPECIFICATION

AMS6509™	REV. B
Issued 2012-05 Revised 2022-09 Superseding AMS6509A	

Steel Bars and Forgings
3.5Cr - 7.5Ni - 16.3Co - 1.75Mo - 0.2W - (0.09 - 0.13C)
Double Vacuum Melted, Normalized, Annealed
(Composition similar to UNS K92731)

RATIONALE

AMS6509B is the result of a Five-Year Review and update of the specification. The revision includes clarification of size limits (1.1, 3.3, 3.5.3.1), composition updates (3.1, 3.1.1), adds strain rate control (3.5.3.1.3), prohibits unauthorized exceptions (3.5.3.1.5, 3.8, 4.4.4, 5.2.1, 8.5. 8.7), adds finish information (8.4), and allows prior revisions (8.6).

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality alloy steel in the form of bars and forgings 199 square inches (1284 cm^2) and under in cross section, and forging stock of any size.

1.2 Application

These products have been used typically for carburized parts requiring high minimum core hardness with a narrow range, reduced distortion and subject to magnetic particle inspection standards, but usage is not limited to such applications.

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.

AMS2251 Tolerances, Low-Alloy Steel Bars

AMS2259 Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels

AMS2300 Steel Cleanliness, Premium Aircraft-Quality Magnetic Particle Inspection Procedure

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS6509B/

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

AMS2750 Pyrometry

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

AS7766 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 A370 Mechanical Testing of Steel Products

ASTM A604 Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets

ASTM E45 Determining the Inclusion Content of Steel

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 E399 Plane-Strain Fracture Toughness of Metallic Materials

ASTM E1077 Estimating the Depth of Decarburization of Steel Specimens

2.3 Definitions

Terms used in AMS are defined in AS7766.

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the following 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	0.09	0.13
Manganese	--	0.1
Silicon	--	0.1
Phosphorus	--	0.008
Sulfur	--	0.006
Chromium	3.0	4.0
Nickel	7.2	7.8
Cobalt	15.5	17.0
Molybdenum	1.5	1.9
Tungsten	0.10	0.30
Titanium	--	0.045
Aluminum	--	0.1
Vanadium	--	0.06
Oxygen	--	0.0020 (20 ppm)
Nitrogen	--	0.0020 (20 ppm)

3.1.1 Producer may test for any element not listed in Table 1 and include this analysis in the report of 4.4. Reporting of any element not listed in the composition table is not a basis for rejection, unless limits of acceptability are specified by the purchaser.

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Melting Practice

Steel shall be multiple melted using vacuum induction melting followed by vacuum arc remelting.

3.3 Condition

The product shall be supplied in the following conditions. Hardness shall be determined in accordance with ASTM A370:

3.3.1 Bars and Forgings

Normalized, annealed (see 3.4), and descaled having hardness not higher than 352 HBW, or equivalent (see 8.2). Bar shall not be cut from plate (also see 4.4.2).

3.3.2 Forging Stock

As ordered by the forging manufacturer.

3.4 Heat Treatment

Bars and forgings shall be normalized by heating to 1785 °F ± 25 °F (974 °C ± 14 °C) for a time commensurate with section thickness, 60 minutes minimum, cooling in air to room temperature and annealed by heating to 1255 °F ± 25 °F (679 °C ± 14 °C) for not less than 2 hours, and cooling in air. Pyrometry shall be in accordance with AMS2750.

3.5 Properties

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

3.5.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, and stock for forging, flash welded rings, or extrusions, etched in hot hydrochloric acid in accordance with ASTM A604 shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A604 shown in Table 2.

Table 2 - Macrostructure limits

Class	Condition	Severity
1	Freckles	A
2	White Spots	A
3	Radial Segregation	B
4	Ring Pattern	B

3.5.2 Micro-Inclusion Rating of Each Heat

No specimen shall exceed the limits shown in Table 3, determined in accordance with ASTM E45, Method D.

Table 3 - Micro-inclusion rating limits

Type	A Thin	A Heavy	B Thin	B Heavy	C Thin	C Heavy	D Thin	D Heavy
Worst Field Severity	1.5	1.0	1.5	1.0	1.5	1.0	1.5	1.0
Worst Field Frequency, maximum	(a)	1	(a)	1	(a)	1	3	1
Total Rateable Fields, Frequency, maximum	(b)	1	(b)	1	(b)	1	8	1

(a) Combined A+B+C; not more than three fields
(b) Combined A+B+C; not more than eight fields

3.5.2.1 A rateable field is defined as one that has a type A, B, C, or D inclusion rating of at least No. 1.0 thin or heavy in accordance with ASTM E45.

3.5.3 Response to Heat Treatment

3.5.3.1 Bars and Forgings

Test specimens extracted from bars and forgings 199 square inches (1284 cm^2) and under in cross section shall conform to the following requirements after being austenitized by heating to 1830 °F ± 25 °F (999 °C ± 14 °C), holding at heat for a time commensurate with section thickness, heating equipment, and procedure used, oil quenched (or equivalent) to below 90 °F (32 °C) followed by cooling to -100 °F (-73 °C) or lower, holding at temperature for 1 hour, +2 hours, -0 hour, warming in air to room temperature, and tempering at 925 °F ± 10 °F (496 °C ± 6 °C) for 8 hours ± 2 hours, and cooling in air (or equivalent).

3.5.3.1.1 Tensile Properties

3.5.3.1.1.1 Longitudinal tensile properties shall be as shown in Table 4. Testing in the longitudinal direction need not be performed on product qualified by testing in the transverse orientation.

Table 4 - Minimum longitudinal tensile properties

Property	Value
Tensile Strength	215 ksi (1482 MPa)
Yield Strength 0.2% Offset	185 ksi (1276 MPa)
Elongation in 4D	13%
Reduction of Area	60%

3.5.3.1.1.2 Transverse tensile properties shall be as shown in Table 5. Transverse properties apply only to product that tensile specimens not less than 1.625 inches (4.128 mm) in length can be taken.

Table 5 - Minimum transverse tensile properties

Property	Value
Tensile Strength	215 ksi (1482 MPa)
Yield Strength 0.2% Offset	185 ksi (1276 MPa)
Elongation in 4D	11%
Reduction of Area	50%

3.5.3.1.1.3 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 in/in and 0.5 in/in (0.05 mm/mm 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 in/in/min and 0.5 in/in/min (0.05 mm/mm/min and 0.5 mm/mm/min).

3.5.3.1.2 Hardness

Shall not be lower than 45 HRC, or equivalent (see 8.2).

3.5.3.1.3 Fracture Toughness

Shall be not lower than 70 ksi √inch (77 MPa √m) K_{IC} or K_Q, determined in accordance with ASTM E399 on any product from which a specimen of a standardized ASTM E399 orientation can be extracted having dimensions not less than 1.50 inches (38.1 mm) in section thickness and not less than 4.00 inches (101.6 mm) in width. Unless otherwise specified by the purchaser, the product can be tested in either the longitudinal L-T or L-R orientation or transverse T-L or R-L orientation.

3.5.3.1.4 Average Grain Size of Bars and Forgings

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

3.5.3.1.5 Mechanical property requirements for bars and forgings outside the size range covered by 1.1 shall be agreed upon between purchaser and producer and reported per 4.4.5.

3.5.3.2 Forging Stock

Specimens extracted from a forged down test coupon subsequently heat treated as in 3.4 and 3.5.3 shall conform to the requirements of 3.5.3.1.1 and 3.5.3.1.2. If specimens taken from the unforged stock and subsequently heat treated as in 3.4 and 3.5.3 conform to the requirements of 3.5.3.1.1 and 3.5.3.1.2, the tests shall be accepted as equivalent to tests of a forged coupon.

3.6 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.

3.6.1 Steel shall be premium aircraft-quality conforming to AMS2300.

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

3.6.3 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.

3.7 Tolerances

3.7.1 Bars

In accordance with AMS2251.

3.8 Exceptions

Any exceptions shall be authorized by the 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

The following requirements are acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1), macrostructure rating (3.5.1), micro-inclusion rating (3.5.2), and response to heat treatment (tensile and hardness) (3.5.3) of each heat.

4.2.1.2 Hardness maximum (3.3.1) of as-supplied normalized and annealed product of each lot of bars and forgings.

4.2.1.3 Average grain size (3.5.3.1.4) of each lot of bars and forgings after heat treatment.

4.2.1.4 Tolerances (3.7) of bars.

4.2.1.5 If forging stock, tests to demonstrate ability to develop required properties (3.5.3.2).

4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.

4.2.2.1 Fracture toughness (3.5.3.1.3) of bars and forgings after heat treatment.

4.2.2.2 Frequency-severity cleanliness rating (3.6.1).

4.2.2.3 Grain flow of die forgings (3.6.3).

4.3 Sampling and Testing

4.3.1 Bars and Forging Stock

In accordance with AMS2370.

4.3.2 Forgings

In accordance with AMS2372.