SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS6509

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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

AMS6509 is a new specification to cover premium aircraft-quality UNS K92731.

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality alloy steel in the form of bars, forgings, and forging stock.

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 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

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

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**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS6509

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

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 A 370 Mechanical Testing of Steel Products

ASTM A 604 Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets

ASTM E 45 Determining the Inclusion Content of Steel

ASTM E 112 Determining Average Grain Size

ASTM E 350 Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

ASTM E 399 Plane-Strain Fracture Toughness of Metallic Materials

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the following percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 350, by spectrochemical methods, 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 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 condition unless another condition is authorized by purchaser; hardness shall be determined in accordance with ASTM A 370:

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 (974 °C ± 14) for 60 minutes + 60, -0, cooling in air to room temperature and annealed by heating to 1255 °F ± 25 (679 °C ± 14) 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 A 370:

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 A 604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A 604 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 E 45, Method A.

TABLE 3 - MICRO-INCLUSION RATING LIMITS

Type	A	B	C	D
Thin	1.5	1.5	1.5	1.5
Thick	1.0	1.0	1.0	1.0

3.5.3 Response to Heat Treatment

3.5.3.1 Bars and Forgings

Test specimens from product 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 (999 °C ± 14), 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, -0, warming in air to room temperature, and tempering at 925 °F ± 10 (496 °C ± 6) for 8 hours ± 2, 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 from which 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%

3.5.3.1.2 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 $\sqrt{inch}$ (77MPa $\sqrt{m}$) K_{IC} or K_Q, determined in accordance with ASTM E 399 on any product from which a specimen of a standardized ASTM E 399 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 E 112.

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 Product ordered hot finished or cold finished or ground, turned, or polished shall, after removal of the standard stock removal allowance in accordance with AS1182, be free from seams, laps, tears, and cracks open to the ground, turned, or polished surface.

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.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection

The vendor of the product shall supply all samples for vendor'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 vendor 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).