AEROSPACE MATERIAL SPECIFICATION

AMS6499	REV. A

Issued 2010-07
Revised 2015-06

Superseding AMS6499

Steel, Bars, Forgings, and Tubing
2.7Si - 0.85Cr - 1.8Ni - 0.4Mo - 0.2V - (0.37 - 0.44C)
Double Vacuum Melted
(Composition similar to UNS K54015)

RATIONALE

AMS6499A is a Five Year Review and update of the specification and revises macrostructure, decarburization and reporting.

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality, 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 requiring a through-hardening steel capable of developing a minimum hardness of 53 HRC in nominal cross-sectional thickness 3.5 inches (89 mm) and under, and being capable of producing finished parts that may be required to pass stringent inspection standards, but usage is not limited to such applications.

1.2.1 Certain design, processing procedures, or environmental conditions may cause these products to become susceptible to stress-corrosion cracking; ARP1110 recommends practices to minimize such conditions.

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

AMS2253 Tolerances, Carbon and Alloy Steel Tubing

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/AMS6499A

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

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

AMS2310 Qualification Sampling of Steels, Transverse Tensile Properties

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

AMS2806 Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys

AMS2808 Identification, Forgings

ARP1110 Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys

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 A370 Mechanical Testing of Steel Products

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

ASTM E112 Determining Average Grain Size

ASTM E350 Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

ASTM E384 Knoop and Vickers Hardness of Materials

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E350, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	min	max
Carbon	0.37	0.44
Manganese	0.50	0.95
Silicon	2.60	2.85
Phosphorus	--	0.015
Sulfur	--	0.010
Chromium	0.65	1.05
Nickel	1.50	2.10
Molybdenum	0.30	0.55
Vanadium	0.10	0.30

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259, except that check analysis limits carbon shall apply over maximum only.

3.2 Melting Practice

Product shall be double vacuum melted, using vacuum induction melting (VIM) followed by vacuum arc consumable electrode remelting (VAR).

3.3 Condition

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

3.3.1 Bars

3.3.1.1 Bars 0.500 inch (12.70 mm) and under in Nominal Diameter or Least Distance between Parallel Sides

Cold finished having tensile strength not higher than 149 ksi (1027 MPa) or equivalent hardness (See 8.2).

3.3.1.2 Bars Over 0.500 inch (12.70 mm) in Nominal Diameter or Least Distance between Parallel Sides

Hot finished, annealed, or normalized and tempered having hardness not higher than 311 HB, or equivalent (See 8.3).

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

3.3.2 Forgings

Normalized and tempered having hardness not higher than 311 HB, or equivalent (See 8.3).

3.3.3 Mechanical Tubing

Annealed, normalized and tempered, or cold finished having hardness not higher than 33 HRC, or equivalent (See 8.3).

3.3.4 Forging Stock

As ordered by the forging manufacturer.

3.4 Properties

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

3.4.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, tube rounds, and forging stock, 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

3.4.2 Average Grain Size of bars, forgings and mechanical tubing.

3.4.3 Shall be ASTM No. 6 or finer, determined in accordance with ASTM E112.

3.4.4 Decarburization

3.4.4.1 Bars and tubing ordered ground, turned or polished shall be free from decarburization on the ground, turned or polished surfaces. Decarburization on tubing ID shall not exceed the maximum depth specified in Table 4.

3.4.4.2 Allowable decarburization of bars, billets, and tube rounds ordered for redrawing or forging or to be specified microstructural requirements shall be agreed upon by purchaser and purchaser.

3.4.4.3 Decarburization of bars that 3.4.3.1 or 3.4.3.2 is not applicable shall be not greater than shown in Table 3.

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

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inch
Up to 0.375, incl	0.015
Over 0.375 to 0.500, incl	0.017
Over 0.500 to 0.675, incl	0.019
Over 0.675 to 1.000, incl	0.022
Over 1.000 to 1.500, incl	0.025
Over 1.500 to 2.000, incl	0.030
Over 2.000 to 2.500, incl	0.035
Over 2.500 to 3.000, incl	0.040
Over 3.000 to 5.000, incl	0.045

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

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
Up to 9.52, incl	0.38
Over 9.52 to 12.70, incl	0.43
Over 12.70 to 15.88, incl	0.48
Over 15.88 to 25.40, incl	0.56
Over 25.40 to 38.10, incl	0.64
Over 38.10 to 50.80, incl	0.76
Over 50.80 to 63.50, incl	0.89
Over 63.50 to 76.20, incl	1.02
Over 76.20 to 127.00, incl	1.14

3.4.4.4 Decarburization of tubing that 3.4.3.1 or 3.4.3.2 is not applicable shall be not greater than shown in Table 4.

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

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inch ID	Total Depth of Decarburization Inch OD
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 depth of decarburization, tubing, SI units

Nominal Wall Thickness Millimeters	Total Depth of Decarburization Millimeter ID	Total Depth of Decarburization Millimeters OD
Up to 2.77, incl	0.20	0.38
Over 2.77 to 5.16, incl	0.25	0.51
Over 5.16 to 10.16, incl	0.30	0.64
Over 10.16 to 15.24, incl	0.38	0.76
Over 15.24 to 25.40, incl	0.43	0.89
Over 25.40	0.51	1.02

3.4.4.5 Decarburization shall be evaluated by one of the two methods of 3.4.4.5.1 or 3.4.4.5.2.

3.4.4.5.1 Metallographic Method

A cross section taken perpendicular to the surface shall be prepared, etched, and visually examined metallographically at a magnification not to exceed 100X. Optical indications of decarburization (including complete decarburization [ferrite] plus partial decarburization) shall not exceed the limits of Tables 3 or Table 4.

3.4.4.5.2 Hardness Traverse Method

The total depth of decarburization shall be determined by a traverse method using microhardness testing in accordance with ASTM E384, at a magnification not exceeding 100X, conducted on a hardened but untempered specimen protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization is defined as the perpendicular distance from the surface to the depth under that surface where there is not further increase in hardness. Such 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.

3.4.4.5.2.1 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 inches (1.65 mm) or less.

3.4.4.5.3 In case of dispute, the total depth of decarburization determined using the microhardness traverse method shall govern.

3.4.5 Response to Heat Treatment of Bars, Forgings and Mechanical Tubing

Specimens shall have the properties of Tables 5 and 6 after heat treatment as follows:

- Normalize by heating to 1750 °F ± 25 (955 °C ± 14), holding at heat for 60 minutes ± 5, and transfer to a furnace at 1290 °F ± 25 (700 °C ± 14), holding at heat for 24 hours ± 1, and cooling to room temperature at a rate equivalent to air cooling
- Hardened by heating to 1720 °F ± 25 (940 °C ± 14), holding at heat for 60 minutes ± 5, and quenching in oil
- Within 4 hours ± 0.4 after quenching, sub-zero treat at -100 °F ± 10 (-73 °C ± 6) holding at temperature for 4 hours ± 0.4
- Air warm to room temperature
- Double tempered by heating to 575 °F ± 10 (302 °C ± 6), holding at heat for 2 hours ± 0.2, cooling in air to room temperature, then temper a second time by reheating to 575 °F ± 10 (302 °C ± 6), holding at heat for 2 hours ± 0.2, and cooling in air.

3.4.5.1 Longitudinal Tensile Properties

Shall be as shown in Table 5; testing in the longitudinal direction need not be performed on product tested in the transverse direction.

Table 5A - Minimum longitudinal tensile properties, inch/pound units

Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %	Reduction of Area %
Longitudinal	305	250	7	30

Table 5B - Minimum longitudinal tensile properties, SI units

Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %	Reduction of Area %
Longitudinal	2100	1725	7	30

3.4.5.2 Transverse Tensile Properties

Shall be as shown in Table 6, determined on specimens selected and prepared in accordance with AMS2310; transverse tensile property requirements of Table 6 apply only to product that tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken.

Table 6A - Minimum transverse tensile properties, inch/pound units

Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %	Reduction of Area %
Transverse	305	250	7	25

Table 6B - Minimum transverse tensile properties, SI units

Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %	Reduction of Area %
Transverse	2100	1725	7	25

3.5 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.

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

3.5.2 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 machined, ground, turned, or polished surface.

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

3.6 Tolerances

3.6.1 Bar

In accordance with AMS2251.

3.6.2 Mechanical Tubing

In accordance with AMS2253.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The purchaser of the product shall supply all samples for purchaser'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 (3.3), macrostructure (3.4.1), average grain size (3.4.2), decarburization (3.4.3), response to heat treatment (3.4.4), and tolerances (3.6) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Frequency-severity cleanliness rating (3.5.1) and grain flow of die forgings (3.5.3) are periodic tests and shall be performed at a frequency selected by the purchaser 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 mechanical tubing shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), the results of tests for composition and macrostructure of each heat, and for condition, average grain size and response to heat treatment 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, AMS6499A, melt practice, product form and size or part number, and quantity. If forgings are supplied, the size and melt source of the stock used to make the forgings shall also be included.

4.4.2 Report the nominal metallurgically worked cross sectional size and the cut size, if different (also see 3.3.1.3).

4.4.3 The producer of forging stock shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations) and the results of tests for composition and macrostructure of each heat, and for response to heat treatment using a test procedure acceptable to purchaser. This report shall include the purchase order number, heat number, AMS6499A, size and quantity.