SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS6304 REV. L

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Superseding AMS6304K

Low-Alloy Steel, Heat-Resistant, Bars, Forgings, and Tubing
0.95Cr - 0.55Mo - 0.30V (0.40 - 0.50C)

(Composition similar to UNS K14675)

RATIONALE

AMS6304L results from a Five Year Review and update of this specification.

1. SCOPE

1.1 Form

1.1.1 This specification covers an aircraft-quality, low-alloy, heat-resistant steel in the form of bars, forgings, mechanical tubing, and forging stock.

1.2 Application

These products have been used typically for parts, such as shafts and fasteners, in service up to 1000 °F (540 °C), 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

AMS2253 Tolerances, Carbon and Alloy Steel Tubing

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

AMS2301 Steel Cleanliness, Aircraft Quality Magnetic Particle Inspection Procedure

AMS2370 Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Wrought Products and Forging Stock

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/AMS6304L

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

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 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 381 Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

ASTM E 384 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 E 350, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Carbon	0.40	0.50
Manganese	0.40	0.70
Silicon	0.15	0.35
Phosphorus	--	0.025
Sulfur	--	0.025
Chromium	0.80	1.10
Molybdenum	0.45	0.65
Vanadium	0.25	0.35
Nickel	--	0.25
Copper	--	0.35

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Condition

The product shall be supplied in the following condition; hardness and tensile strength shall be determined in accordance with ASTM A 370:

3.2.1 Bars

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

3.2.1.1 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 125 ksi (862 MPa) or equivalent hardness (See 8.2).

3.2.1.2 Bars Over 0.500 Inch in Nominal Diameter or Least Distance Between Parallel Sides

Hot finished and annealed unless otherwise ordered, having hardness not higher than 229 HB, or equivalent (See 8.3). Bars ordered cold finished may have hardness as high as 248 HB, or equivalent (See 8.3).

3.2.2 Forgings

Annealed having hardness not higher than 248 HB, or equivalent (See 8.3).

3.2.3 Mechanical Tubing

Cold finished unless otherwise ordered, having hardness not higher than 25 HRC, or equivalent (See 8.3). Tubing ordered hot finished and annealed shall have hardness not higher than 99 HRB, or equivalent (See 8.3).

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 A 370:

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 E 381, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM E 381 shown in Table 2.

TABLE 2 - MACROSTRUCTURE LIMITS

Cross-Section Area Square Inches	Macrographs
Up to 36, incl	S2 - R1 - C2
Over 36 to 100, incl	S2 - R2 - C3

3.3.1.1 Macrostructure examination is not required for hollow tubes that are produced directly from ingots or blooms unless specified by purchaser, in which case the purchaser shall specify standards to be used.

3.3.2 Average Grain Size of Bars, Forgings and Tubing

Shall be ASTM No. 5 or finer, determined in accordance with ASTM E 112.

3.3.3 Decarburization

3.3.3.1 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 total depth specified in Table 4.

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

3.3.3.3 Decarburization of bars to which 3.3.3.1 or 3.3.3.2 is not applicable shall be not greater than 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 Inch
Up to 0.375, incl	0.015
Over 0.375 to 0.500, incl	0.017
Over 0.500 to 0.625, incl	0.019
Over 0.625 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 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 9.52, 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 101.60, incl	1.14

3.3.3.4 Decarburization of tubing to which 3.3.3.1 or 3.3.3.2 is not applicable shall be not greater than shown in Table 4.

TABLE 4A - MAXIMUM TOTAL DEPTH OF DECARBURIZATION, INCH/POUND UNITS

Nominal Wall Thickness Inches	Total Depth of Decarburization Inch ID	Total Depth of Decarburization Inch OD
Up to 0.109, incl	0.008	0.020
Over 0.109 to 0.203, incl	0.010	0.025
Over 0.203 to 0.400, incl	0.012	0.030
Over 0.400 to 0.600, incl	0.015	0.035
Over 0.600 to 1.000, incl	0.017	0.040
Over 1.000	0.020	0.045

TABLE 4B - MAXIMUM TOTAL DEPTH OF DECARBURIZATION, 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	0.51
Over 2.77 to 5.16, incl	0.25	0.64
Over 5.16 to 10.16, incl	0.30	0.76
Over 10.16 to 15.24, incl	0.38	0.89
Over 15.24 to 25.40, incl	0.43	1.02
Over 25.40	0.51	1.14

3.3.3.5 Decarburization shall be measured by the metallographic method, by the HR30N scale hardness testing method, or by a traverse method using microhardness testing in accordance with ASTM E 384. The hardness method(s) shall be conducted on a hardened but untempered specimen protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization, when measured by a hardness method, is defined as the perpendicular distance from the surface to the depth under that surface below that there is no 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. In case of dispute, the depth of decarburization determined using the microhardness traverse method shall govern.

3.3.3.5.1 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 inch (1.65 mm) or less.

3.3.4 Response to Heat Treatment

Specimens as in 4.3.3 shall have hardness at the center of the specimen not lower than 331 HB, or equivalent (See 8.3), for cross-sections 2 inches (50.8 mm) and under and not lower than 302 HB, or equivalent (See 8.3), for larger cross-sections after being heated to 1750 °F ± 25 (954 °C ± 14), held at heat for 60 to 90 minutes, cooled at a rate equivalent to still air cooling, reheated to 1100 °F ± 15 (593 °C ± 8), held at heat for 6 hours ± 0.25, and cooled in air.

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 aircraft-quality conforming to AMS2301.

3.4.2 Bars and mechanical tubing ordered hot rolled or cold drawn 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.

3.4.3 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

Shall conform to all applicable requirements of AMS2251.

3.5.2 Mechanical Tubing

Shall conform to all applicable requirements of AMS2253.

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

Composition (3.1), condition (3.2), macrostructure (3.3.1), average grain size (3.3.2), decarburization (3.3.3), quality (3.4.1) and tolerances (3.5) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Response to heat treatment (3.3.4) and grain flow of die forgings (3.4.3) are periodic tests and shall be performed at a frequency selected by the vendor 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.

4.3.3 Specimens for response to heat treatment (3.3.4) shall be not shorter than twice the nominal diameter or distance between parallel sides or 6 inches (152 mm), whichever is less, and shall have the full cross-section of the product that they were cut from except that sections over 2 to 4 inches (over 51 to 102 mm), inclusive, in nominal diameter or least distance between parallel sides shall be reduced to 2.00 inches ± 0.01 (51 mm ± 0.03) and sections over 4 inches (102 mm) shall be reduced to 4.00 inches ± 0.01 (101.6.mm ± 0.03)

4.4 Reports

4.4.1 The vendor of bars, forgings and tubing shall furnish with each shipment a report showing the results of tests for composition, macrostructure, and frequency-severity cleanliness rating of each heat, and for average grain size 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, AMS6304L, 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.

4.4.2 If the ship size/shape is cut from a larger cross section, report the nominal metallurgically worked size (See 3.2.1).

4.4.3 The vendor of forging stock shall furnish with each shipment a report showing the results of tests for composition, macrostructure and the frequency-severity cleanliness rating of each heat. This report shall include the purchase order number, heat number, AMS6304L, size and quantity.