AEROSPACE MATERIAL SPECIFICATION

AMS6481™	REV. E

Issued 1998-10
Reaffirmed 2006-04
Revised 2022-01

Superseding AMS6481D

Steel Bars, Forgings, Mechanical Tubing, and Forging Stock Nitriding 3Cr - 1Mo - 0.2V - (0.29 - 0.36C) Premium Aircraft-Quality for Bearing Applications Double Vacuum Melted

(Composition similar to UNS K24340)

RATIONALE

This standard is the result of a Five-Year Review and update of the document. The revision includes update of title to match the scope, revision of composition test method (3.1), deletes “unless otherwise ordered” wording (3.3.1.2, 3.3.3), adds macrostructure requirements (3.4.1, 8.9), updates decarburization (3.4.5.5), prohibits unauthorized exceptions (3.7, 4.4.4, 5.2.1.1, 8.7), allows prior revisions (8.8), and adds instruction on sizing (8.6).

1. SCOPE

1.1 Form

This specification covers a nitriding grade of 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 nitrided parts such as bearings, operating under heavy loads and high speeds at moderate temperatures, subject to very rigid inspection standards, and requiring higher surface hardness, high core toughness, and less distortion than parts made from steel requiring quenching to case harden, 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.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS6481E/

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

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

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 A751 Chemical Analysis of Steel Products

ASTM E45 Determining the Inclusion Content of Steels

ASTM E112 Determining Average Grain Size

ASTM E140 Hardness Conversion Tables for Metals Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

ASTM E1077 Estimating the Depth of Decarburization of Steel Specimens

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 other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	Min	Max
Carbon	0.29	0.36
Manganese	0.40	0.70
Silicon	0.10	0.40
Phosphorus	--	0.015
Sulfur	--	0.005
Chromium	2.80	3.30
Nickel	--	0.30
Molybdenum	0.70	1.20
Vanadium	0.15	0.35
Copper	--	0.10

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Melting Practice

Steel shall be double vacuum melted, using vacuum induction melting followed by vacuum arc consumable electrode remelting.

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

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

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 125 ksi (862 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 and annealed, having hardness not higher than 255 HBW, or equivalent (see 8.3). Bars ordered cold finished may have hardness as high as 269 HBW or equivalent (see 8.3).

3.3.2 Forgings

As ordered.

3.3.3 Mechanical Tubing

Cold finished, having hardness not higher than 272 HBW, or equivalent (see 8.3). Tubing ordered hot finished and annealed shall have hardness not higher than 248 HBW 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; mechanical tests shall be performed in accordance with ASTM A370:

3.4.1 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 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

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

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

3.4.1.2 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).

3.4.2 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	1.0	1.0	1.0	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	5	1

a - Combined A+B+C, not more than three fields.
b - Combined A+B+C, not more than eight fields.

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

3.4.3 Average Grain Size of Bars, Forgings, and Tubing

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

3.4.4 Response to Heat Treatment of Bars, Forgings, Tubing, and Forging Stock

The product (see 4.3.3) shall have the properties shown in Table 4 after being austenitized by heating to 1690 °F ± 15 °F (921 °C ± 10 °C), holding 1 to 3 hours, and quenching in oil, followed by tempering for 2 hours minimum at not lower than 1110 °F (599 °C).

Table 4 - Longitudinal mechanical properties

Property	Value
Tensile Strength, min	165 ksi (1138 MPa)
Yield Strength 0.2%, min	138 ksi (951 MPa)
Elongation in 4D, min	13%
Charpy V-notch, min	50 ft-lb (68 J)
Hardness	352 to 388 HBW, or equivalent (see 8.3)

3.4.5 Decarburization

3.4.5.1 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 6.

3.4.5.2 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.

3.4.5.3 Decarburization of bars that 3.4.5.1 or 3.4.5.2 is not applicable shall be not greater than shown in Table 5.

Table 5A - Maximum depth of decarburization, inch/pound units

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inches
Up to 0.500, incl	0.015
Over 0.500 to 1.000, incl	0.030
Over 1.000 to 2.000, incl	0.040
Over 2.000 to 3.000, incl	0.050
Over 3.000 to 4.000, incl	0.065
Over 4.000 to 5.000, incl	0.095

Table 5B - Maximum depth of decarburization, SI units

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
Up to 12.70, incl	0.38
Over 12.70 to 25.40, incl	0.76
Over 25.40 to 50.80, incl	1.02
Over 50.80 to 75.20, incl	1.27
Over 75.20 to 101.60, incl	1.65
Over 101.60 to 127.00, incl	2.41

3.4.5.4 Decarburization of tubing that 3.4.5.1 or 3.4.5.2 is not applicable shall be not greater than shown in Table 6.

Table 6A - Maximum depth of decarburization, inch/pound units

Nominal Outside Diameter Inches	Total Depth of Decarburization Inches
Up to 1.000, incl	0.025
Over 1.000 to 2.000, incl	0.035
Over 2.000 to 3.000, incl	0.045
Over 3.000 to 4.000, incl	0.055
Over 4.000 to 5.000, incl	0.080

Table 6B - Maximum depth of decarburization, SI units

Nominal Outside Diameter Millimeters	Total Depth of Decarburization Millimeters
Up to 25.40, incl	0.64
Over 25.40 to 50.80, incl	0.89
Over 50.80 to 75.20, incl	1.14
Over 75.20 to 101.60, incl	1.40
Over 101.60 to 127.00, incl	2.03

3.4.5.5 Decarburization shall be evaluated by one of the two methods of 3.4.5.5.1 or 3.4.5.5.2.

3.4.5.5.1 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 (ferrite) or partial decarburization exceeding the limits of Tables 5 or 6.

3.4.5.5.2 Hardness (Microindentation) Traverse 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 5 or 6.

3.4.5.6 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.

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

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

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 Bars

In accordance with AMS2251.

3.6.2 Mechanical Tubing

In accordance with AMS2253.

3.7 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.4.

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 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), micro-inclusion rating (3.4.2), average grain size (3.4.3), response to heat treatment (3.4.4), decarburization (3.4.5), 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 rating (3.5.1) and grain flow of die forgings (3.5.2) 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.

4.3.3 Samples for Response to Heat Treatment

Samples shall be extracted from the full cross section of the product, except that product over 2 inches (50 mm) in nominal diameter, or least distance between parallel sides may be forged or machined to 2 inches (50 mm) before testing.

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, macrostructure, and micro-inclusion rating of each heat and for average grain size and response to heat treatment, including the tempering temperature used, 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, AMS6481E, 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 3.3.1).

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, micro-inclusion rating and response to heat treatment of each heat, and the results of any additional property requirements imposed by 8.6. This report shall include the purchase order number, heat number, AMS6481E, size, and quantity.