

**AEROSPACE
MATERIAL
SPECIFICATION****SAE** AMS6481**REV. C**Issued 1998-10
Revised 2012-08

Superseding AMS6481B

Steel Bars, forgings, and tubing, Nitriding
3Cr - 1Mo - 0.2V - (0.29 - 0.36C)
Premium Aircraft-Quality for Bearing Applications
Double Vacuum Melted

(Composition similar to UNS K24340)

RATIONALE

AMS6481C results from a Five Year Review and update of this specification.

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, and subject to very rigid inspection standards, and requiring highest 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 supplied 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.

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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
- 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

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 Steels
- 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 384 Knoop and Vickers Hardness of 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 or by spectrochemical 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 A 370:

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, unless otherwise ordered, having hardness not higher than 255 HB, or equivalent (See 8.3). Bars ordered cold finished may have hardness as high as 269 HB or equivalent (See 8.3).

3.3.2 forgings

As ordered.

3.3.3 Mechanical Tubing

Cold finished, unless otherwise ordered, having hardness not higher than 272 HB, or equivalent (See 8.3). Tubing ordered hot finished and annealed shall have hardness not higher than 248 HB 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 A 370:

3.4.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, tube rounds (solid, not hollow), or forging stock, 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

| 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 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.

3.4.2 Micro-Inclusion Rating of Each Heat

No specimen shall exceed the limits shown in Table 3, determined in accordance with ASTM E 45, Method D.

TABLE 3 - MICRO-INCLUSION RATING LIMITS

| Type | A | | B | | C | | D | |
|---|------|-------|------|-------|------|-------|------|-------|
| | Thin | Heavy | Thin | Heavy | Thin | Heavy | Thin | 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 3 fields
b - Combined A+B+C, not more than 8 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 with Jernkontoret chart, Plate I-r, ASTM E 45.

3.4.3 Average Grain Size of Bars, forgings and Tubing

Shall be ASTM No. 6 or finer determined in accordance with ASTM E 112.

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 $1690^{\circ}\text{F} \pm 15$ ($921^{\circ}\text{C} \pm 10$), holding at least 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 (1137 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 HB, 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 vendor.

3.4.5.3 Decarburization of bars to which 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 Inch |
|--|---|
| 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 to which 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 Inch |
|---------------------------------------|---|
| 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 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 which 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.

3.4.5.6 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.

3.5 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.

3.5.1.1 Bars and mechanical tubing ordered hot rolled or cold drawn, ground, turned, or polished shall, after removal of the standard machining allowance in accordance with AS1182, be free from seams, laps, tears, and cracks open to the ground, turned, or polished surface.

3.5.2 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.

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 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 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 Samples for Response to Heat Treatment

Samples shall be extracted from the full cross section of the product, except that product over 2 inches (50.8 mm) in nominal diameter, or least distance between parallel sides may be forged or machined to 2 inches (50.8 mm) before testing.

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 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, AMS6481C, 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 vendor of forging stock shall furnish with each shipment a report showing the results of tests for composition, macrostructure, micro-inclusion rating and response to heat treatment of each heat. This report shall include the purchase order number, heat number, AMS6481C, size and quantity.

4.5 Resampling and Retesting

4.5.1 Bars, Mechanical Tubing, and Forging Stock

In accordance with AMS2370.

4.5.2 forgings

In accordance with AMS2372.