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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

# AEROSPACE MATERIAL SPECIFICATION

SAE AMS 6481

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Submitted for recognition as an American National Standard

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



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 following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2251 Tolerances, Low-Alloy Steel Bars
MAM 2251 Tolerances, Metric, Low-Alloy Steel Bars
AMS 2253 Tolerances, Carbon and Alloy Steel Tubing
MAM 2253 Tolerances, Metric, Carbon and Alloy Steel Tubing
AMS 2259 Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
AMS 2300 Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure



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2.1 (Continued):

MAM 2300 Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
AMS 2370 Quality Assurance Sampling and Testing of Carbon and Low-Alloy Steel, Wrought Products and Forging Stock
AMS 2372 Quality Assurance Sampling and Testing of Carbon and Low-Alloy Steel Forgings
AMS 2806 Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat Resistant Steels and Alloys
AMS 2808 Identification, Forgings

AS1182 Standard Machining Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

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 spectrographic 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 AMS 2259.

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:

3.3.1.1 Bars 0.500 inch (12.70 mm) and Under in Nominal Diameter or Distance Between Parallel Sides: Cold finished having tensile strength not higher than 125 ksi (862 MPa) or equivalent hardness (See 8.1)

3.3.1.2 Bars over 0.500 inch (12.70 mm) in Nominal Diameter or 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.

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 8.2). Tubing ordered hot finished and annealed shall have hardness not higher than 248 HB or equivalent.

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, 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 for product 36 square inches (230 $cm^2$) and under in nominal cross-sectional area 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 |

3.4.2 Micro-Inclusion Rating: 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 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 | a | 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 III, ASTM E 45.

3.4.3 Average Grain Size: Shall be ASTM No 6 or finer determined in accordance with ASTM E 112.

3.4.4 Response to Heat Treatment: The product (See 4.3.3) shall have the properties shown in Table 4 after being austenitized by heating to 1690 °F ± 15 (921 °C ± 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 |

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.

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 | 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 | Depth of Decarburization Millimeters |
|---|---|
| Up to 12.50, incl | 0.38 |
| Over 12.50 to 25.00, incl | 0.75 |
| Over 25.00 to 50.00, incl | 1.00 |
| Over 50.00 to 75,00, incl | 1.25 |
| Over 75.00 to 100.00, incl | 1.65 |
| Over 100.00 to 125.00, incl | 2.40 |

3.4.5.4 Decarburization of all 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 | 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 | Depth of Decarburization Millimeters |
|---|---|
| Up to 25.00, incl | 0.62 |
| Over 25.00 to 50.00, incl | 0.88 |
| Over 50.00 to 75.00, incl | 1.12 |
| Over 75.00 to 100.00, incl | 1.40 |
| Over 100.00 to 127.00, incl | 2.00 |



3.4.5.5 Decarburization shall be measured by the metallographic method, by HR 30 N scale hardness testing method, or by the microhardness transverse method 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 decarburization on the adjacent surface. In case of dispute, the depth of decarburization determined using the microhardness transverse 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 (0.12 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 AMS 2300 or MAM 2300.

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 surfaces.

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 re-entrant grain flow.

3.6 Tolerances:

Shall be as follows:

3.6.1 Bars: In accordance with AMS 2251 or MAM 2251.

3.6.2 Mechanical Tubing: In accordance with AMS 2253 or MAM 2253.

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: Grain flow of die forgings (3.5.2) is a periodic test and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing:

Shall be as follows:

4.3.1 Bars, Mechanical Tubing, and Forging Stock: In accordance with AMS 2370.