

AEROSPACE MATERIAL SPECIFICATION

Issued JAN 1976
Revised AUG 2005
Superseding AMS 6491B

Steel Bars, Forgings, and Tubing
4.1Cr - 4.2Mo - 1.0V (0.80 - 0.85C)
Premium Aircraft-Quality for Bearing Applications, Double Vacuum Melted
(Composition similar to UNS T11350)

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, such as bearings operating under heavy loads and high speeds at moderate temperatures and subject to very rigid inspection standards, 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2251	Tolerances, Low-Alloy Steel Bars
AMS 2253	Tolerances, Carbon and Alloy Steel Tubing
AMS 2259	Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
AMS 2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure
AMS 2370	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel, Wrought Products and Forging Stock

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2.1 (Continued)

AMS 2372	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Forgings
AMS 2375	Control of Forgings Requiring First Article Approval
AMS 2806	Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Heat and Corrosion-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, P.O. Box C700, West Conshohocken, PA 19428-2959 or 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 Steel
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	Microindentation 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	0.80	0.85
Manganese	0.15	0.35
Silicon	--	0.25
Phosphorus	--	0.015
Sulfur	--	0.008
Chromium	4.00	4.25
Molybdenum	4.00	4.50
Vanadium	0.90	1.10
Nickel	--	0.15
Cobalt	--	0.25
Tungsten	--	0.25
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 practice followed by vacuum 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 Least Distance Between Parallel Sides: Cold finished having tensile strength not higher than 120,000 psi (825 MPa) or equivalent hardness (See 8.2).

3.3.1.2 Bars Over 0.500 inch (12.750 mm) 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).

3.3.2 Forgings: As ordered.

3.3.3 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).

3.3.4 Forging Stock: As ordered by the forging manufacturer.

3.4 Properties:

The product shall conform to the following requirements: hardness testing shall be performed in accordance with ASTM A 370.

3.4.1 Macrostructure: Visual examination of transverse sections from bars, billets, tube rounds, and 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 (232 cm²) 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 Limits

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 of 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	x	1	x	1	x	1	3	1
Total Rateable Fields, Frequency, maximum	y	1	y	1	y	1	8	1
^x Combined A+B+C, not more than 3 fields								
^y 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 (See 8.4).

3.4.3 Response to Heat Treatment: Specimens as in 4.3.3 protected by suitable means or treated in a neutral atmosphere or neutral salt to minimize scaling and prevent either carburization or decarburization, shall have substantially uniform hardness not lower than 60 HRC after being heated to 2025 to 2050 °F (1107 to 1121 °C) by any convenient means, held to equalize at temperature, and either quenched into salt bath at 1100 to 1150 °F (593 to 621 °C), held in salt bath for 2 min ± 0.2, and air cooled to room temperature or directly air cooled to room temperature, and tempered for 2 h ± 0.25 at 1000 to 1025 °F (538 to 552 °C).

3.4.4 Average Grain Size: Shall be ASTM No. 7 or finer, determined in accordance with ASTM E 112 after austenitizing and quenching as in 3.4.3.

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 5.

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 4.

Table 4A - Maximum 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 4B - Maximum Decarburization, SI Units

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total 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 5.

TABLE 5A - Maximum 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 5B - Maximum Decarburization, SI Units

Nominal Outside Diameter Millimeters		Total 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 125.00, incl	2.00

3.4.5.5 Decarburization shall be measured by the microscopic method, by HR30N scale hardness testing method, or by the microhardness 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 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 traverse method shall govern.

3.4.5.5.1 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.

3.5 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.

3.5.2 Bars and mechanical tubing ordered hot rolled or cold drawn, or 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.

3.5.3 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:

Shall be as follows:

3.6.1 Bars: In accordance with AMS 2251.

3.6.2 Mechanical Tubing: In accordance with AMS 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), response to heat treatment (3.4.3), average grain size (3.4.4), decarburization (3.4.5), and tolerance (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 (3.5.3) 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:

Shall be as follows:

- 4.3.1 Bars, Forging Stock, and Mechanical Tubing: In accordance with AMS 2370.
- 4.3.2 Forgings: In accordance with AMS 2372.
- 4.3.3 Samples for response to heat treatment (3.4.3) shall be as follows:
- 4.3.3.1 Specimens from bars shall be full cross-sections of the bar, ground on both faces normal to the axis so that length is 0.500 inch \pm 0.010 (12.70 mm \pm 0.25).
- 4.3.3.2 Specimens from mechanical tubing shall be full cross-sections of the tubing, shall have wall thickness not over 0.625 inch (15.88 mm), with wall thicknesses over 0.625 inch (15.88 mm) being turned to 0.625 inch \pm 0.010 (15.88 mm \pm 0.25), and shall be ground on both faces so that length is 0.500 inch \pm 0.010 (12.70 mm \pm 0.25).

4.4 Approval:

When specified, approval and control of forgings shall be in accordance with AMS 2375.

4.5 Reports:

The vendor of the product shall furnish with each shipment a report showing the results of tests for composition, macrostructure and micro-inclusion rating for each heat, and for condition (hardness), response to heat treatment and 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, AMS 6491C, size, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.6 Resampling and Retesting:

Shall be as follows:

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

4.6.2 Forgings: In accordance with AMS 2372.

5. PREPARATION FOR DELIVERY:

5.1 Sizes:

Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing will be acceptable in mill lengths of 6 to 20 feet (1.8 to 6.1 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).

5.2 Identification:

Shall be as follows:

5.2.1 Bars and Mechanical Tubing: In accordance with AMS 2806.

5.2.2 Forgings: In accordance with AMS 2808.

5.2.3 Forging Stock: As agreed upon by purchaser and vendor.

5.3 Packaging:

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

5.4 Protective Treatment:

Ground and turned product shall be protected from corrosion prior to shipment.