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400 COMMONWEALTH DRIVE WARRENDALE PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 6488D
Superseding AMS 6488C

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STEEL BARS AND FORGINGS
5.0Cr - 1.3Mo - 0.50V (0.38 - 0.43C)
Premium Aircraft-Quality

UNS T20811

1. SCOPE:

1.1 Form: This specification covers a low-alloy steel in the form of bars, forgings, and forging stock.

1.2 Application: Primarily for parts requiring a steel capable of through-hardening to a minimum hardness of 50 HRC in section thicknesses up to 12 in. (300 mm) with relatively high levels of strength, fatigue resistance, ductility, and thermal stability in service from -100° to +1000°F (-75° to +540°C).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Standards shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2251 - Tolerances, Low-Alloy Steel Bars
MAM 2251 - Tolerances, Metric, Low-Alloy Steel Bars
AMS 2259 - Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
AMS 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
MAM 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
AMS 2310 - Qualification Sampling of Steels, Transverse Tensile Properties
AMS 2350 - Standards and Test Methods
AMS 2370 - Quality Assurance Sampling of Carbon and Low-Alloy Steels, Wrought Products Except Forgings and Forging Stock
AMS 2372 - Quality Assurance Sampling of Carbon and Low-Alloy Steels, Forgings and Forging Stock
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

2.1.2 Aerospace Standards:

AS 1182 - Standard Machining Allowance, Aircraft Quality and Premium Quality Steel Products

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A370 - Mechanical Testing of Steel Products
ASTM A604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E112 - Determining Average Grain Size
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E350, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other analytical methods approved by purchaser:

	min	max
Carbon	0.38	0.43
Manganese	0.20	0.40
Silicon	0.80	1.00
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	4.75	5.25
Molybdenum	1.20	1.40
Vanadium	0.40	0.60
Nickel	--	0.25
Copper	--	0.35

3.1.1 Check Analysis: Composition variations shall meet the requirements of Ø AMS 2259.

3.2 Condition: The product shall be supplied in the following condition; Ø hardness and tensile strength shall be determined in accordance with ASTM A370.

3.2.1 Bars:

3.2.1.1 Bars 0.500 In. (12.50 mm) and Under in Nominal Diameter or Distance Between Parallel Sides: Cold finished having tensile strength not higher than 135,000 psi (930 MPa) or equivalent hardness.

3.2.1.2 Bars Over 0.500 In. (12.50 mm) in Nominal Diameter or Distance Between Parallel Sides: Hot finished having hardness not higher than 235 HB or equivalent except that bars ordered cold finished may have hardness as high as 255 HB or equivalent.

3.2.2 Forgings: Annealed having hardness not higher than 235 HB or equivalent.

3.2.3 Forging Stock: As ordered by the forging manufacturer.

3.3 Properties: The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A370:

3.3.1 Macrostructure: Visual examination of transverse sections as in 4.3.3 Ø from bars, billets, and forging stock, etched in accordance with ASTM A604 in hot hydrochloric acid (1:1) at 160° - 180°F (70° - 80°C) for sufficient time to develop a well-defined macrostructure, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections

3.3.1 (Continued):

for product 36 sq in. (230 cm^2) and under in nominal cross-sectional area shall be no worse than the following macrographs of ASTM A604; macrostructure standards for product over 36 sq in. (230 cm^2) in nominal cross-sectional area shall be as agreed upon by purchaser and vendor.

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

3.3.2 Decarburization:

3.3.2.1 Bars ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces.

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

3.3.2.3 Decarburization of bars to which 3.3.2.1 or 3.3.2.2 is not applicable shall be not greater than shown in Table I.

TABLE I

Nominal Diameter or Distance Between Parallel Sides Inches	Depth of Decarburization Inch
Up to 0.375, incl	0.010
Over 0.375 to 0.500, incl	0.015
Over 0.500 to 0.625, incl	0.020
Over 0.625 to 1.000, incl	0.025
Over 1.000 to 2.000, incl	0.035
Over 2.000 to 3.000, incl	0.048
Over 3.000 to 4.000, incl	0.062
Over 4.000 to 5.000, incl	0.094
Over 5.000	0.125

TABLE I SI

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetres
Up to 9.50, incl	0.25
Over 9.50 to 12.50, incl	0.38
Over 12.50 to 15.75, incl	0.50
Over 15.75 to 25.00, incl	0.62
Over 25.00 to 50.00, incl	0.88
Over 50.00 to 75.00, incl	1.20
Over 75.00 to 100.00, incl	1.55
Over 100.00 to 125.00, incl	2.35
Over 125.00	3.12

3.3.2.4 Decarburization shall be measured by the microscopic method or by Rockwell Superficial 30-N scale or equivalent hardness testing method on hardened but untempered specimens 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 or lack of decarburization thereon.

3.3.2.4.1 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 in. (0.12 mm) and the width is 0.065 in. (1.65 mm) or less.

3.3.3 Properties After Heat Treatment: Test specimens as in 4.3.5 shall meet the requirements of 3.3.3.1, 3.3.3.2, and 3.3.3.3 after being hardened by heating to 1850°F ± 25 (1010°C ± 15), holding at heat for 15 - 45 min., and cooling in air to room temperature and tempered three times by heating to not lower than 1000°F (540°C), holding at heat for 2 - 3 hr, and cooling in air.

3.3.3.1 Tensile Properties:

3.3.3.1.1 Longitudinal: Shall be as follows; testing in the longitudinal direction need not be performed on product tested in the transverse direction:

Tensile Strength, min	260,000 psi (1795 MPa)
Yield Strength at 0.2% Offset, min	215,000 psi (1480 MPa)
Elongation in 4D, min	8%
Reduction of Area, min	30%

3.3.3.1.2 Transverse: Shall be as follows, determined on specimens selected and
Ø prepared in accordance with AMS 2310 except as specified in 4.3.5; transverse requirements are applicable only to product sufficiently large to yield tensile specimens not less than 4.50 in. (112.5 mm) in length.

Tensile Strength	260,000 - 280,000 psi (1795 - 1930 MPa)
Yield Strength at 0.2% Offset, min	215,000 psi (1480 MPa)
Reduction of Area, min	
Individual Value	6%
Average Value	15%

3.3.3.2 Hardness: Should be 50 - 56 HRC or equivalent but the product shall not be rejected on the basis of hardness if the tensile property requirements are met.

3.3.3.3 Grain Size: Predominantly 7 or finer with occasional grains as large as
Ø 5 permissible, except predominantly 5 or finer with occasional grains as large as 3 permissible on bars and forgings over 2.50 in. (62.5 mm) in nominal cross-sectional dimension, determined in accordance with ASTM E112.

3.4 Quality:

3.4.1 Steel shall be premium aircraft-quality conforming to AMS 2300, except
Ø vacuum are melting is not required.

3.4.2 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.

3.4.2.1 Bars ordered ground, turned, or polished shall be free from seams, laps, tears, and cracks open to the ground, turned, or polished surface.

3.4.2.2 Product ordered to surface conditions other than ground, turned, or polished shall, after removal of the standard machining allowance, be free from seams, laps, tears, cracks, and other defects exposed to the machined surfaces. Standard machining allowance shall be in accordance with AS 1182.

3.5 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight bars will be acceptable in mill lengths of 6 - 20 ft (2 - 6 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 ft (3 m).

3.6 Tolerances: Unless otherwise specified, tolerances for bars shall conform to all applicable requirements of AMS 2251 or MAM 2251.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all Ø samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Except as specified in 3.3.3.1.1, tests to determine Ø conformance to all technical requirements of this specification are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Preproduction Tests: Tests of forgings to determine conformance to all technical requirements of this specification when AMS 2375 is specified, Ø are classified as preproduction tests and shall be performed on the first-article shipment of a forging to a purchaser, when a change in material or processing, or both, requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.2.1 For direct U.S. Military procurement of forgings, substantiating test data and, when requested, preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be in accordance with the following; when consumable electrode remelted steel is supplied, a heat shall be the consumable electrode remelted ingots produced from steel originally melted as a single furnace charge.

4.3.1 Bars: AMS 2370.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 Specimens for composition determination (3.1) shall be selected from each heat except that carbon and manganese shall be determined on samples from each consumable electrode remelted ingot.

4.3.4 Samples for macrostructure (3.3.1) testing shall be full cross-sectional specimens obtained from the finished billet or suitable rerolled product representing the top and bottom of at least the first, middle, and last usable ingots of each heat.

4.3.5 Specimens for tensile testing (3.3.3.1) shall be machined from samples taken from the product after heat treatment as in 3.3.3. Specimens for transverse tensile testing shall be taken from within 1 in. (25 mm) of the mid-length of the heat treated test samples.

4.3.5.1 Bars and Forging Stock:

4.3.5.1.1 Product 5.000 In. (125.00 mm) and Under in Nominal Diameter or Equivalent Section: Samples shall be the full cross-section of the product.

4.3.5.1.2 Product Over 5.000 In. (125.00 mm) in Nominal Diameter or Equivalent Section: Samples shall be reduced to 5.0 in. (125 mm) in diameter or equivalent section by rolling or forging. When agreed upon by purchaser and vendor, samples 5 in. (125 mm) in diameter may be machined from the product.

4.3.5.2 Forgings: Specimens shall be obtained from complete forgings. Number, size, and location of specimens shall be as specified by purchaser.

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

4.5 Reports:

4.5.1 The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition, macrostructure, and frequency-severity cleanliness rating of each heat, the results of tests on each lot to determine conformance to the decarburization requirements and to tensile properties and grain size after heat treatment, and the specific tempering temperature used to develop reported tensile properties. This report shall include the purchase order number, heat number, AMS 6488D, size, and quantity from each heat. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.5.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 6488D, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of test to determine conformance.

4.6 Resampling and Retesting: Shall be in accordance with the following:

4.6.1 Bars: AMS 2370.

4.6.2 Forgings and Forging Stock: AMS 2372.

5. PREPARATION FOR DELIVERY:

5.1 Identification: The product shall be identified as follows: