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400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 6485E
Superseding AMS 6485D

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

UNS T20811

1. SCOPE:

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

1.2 Application: Primarily for parts requiring a combination of relatively-high strength, fatigue resistance, toughness, ductility, and thermal stability for operation between -100° and +1000°F (-75° and +540°C) and where such parts may require welding during fabrication.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) and Aerospace Standards (AS) 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
AMS 2259 - Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
AMS 2301 - Aircraft Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
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 E21 - Elevated Temperature Tension Tests of Metallic Materials
ASTM E112 - Estimating the Average Grain Size of Metals
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
ASTM E381 - Macroetch Testing, Inspection, and Rating Steel Products Comprising Bars, Billets, Blooms, and Forgings

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	--	0.020
Sulfur	--	0.020
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 applicable requirements of AMS 2259.

3.2 Condition: The product shall be supplied in the following condition; 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: As ordered.

3.2.3 Forging Stock: As ordered by the forging manufacturer.

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

3.3.1 Macrostructure: Visual examination of transverse sections as in 4.3.3 from bars, billets, and forging stock, etched in accordance with ASTM E381 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 shall be no worse than the following macrographs of ASTM E381:

Section Size		
Square Inches	Square Centimetres	Macrographs
Up to 36, incl	Up to 230, incl	S2 - R1 - C2
Over 36 to 100, incl	Over 230 to 645, incl	S2 - R2 - C3
Over 100	Over 645	As agreed upon

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: Specimens shall meet the requirements of 3.3.3.1, 3.3.3.2, and 3.3.3.3 after being austenitized 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 a temperature 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: These requirements apply to specimens taken from bars and from forging stock 25 sq in. (160 cm^2) and under in cross-sectional area, from forgings with axis approximately parallel to the forging flow lines, and from coupons of forging stock over 25 sq in. (160 cm^2) in cross-sectional area forged to 25 sq in. (160 cm^2) prior to heat treatment as in 3.3.3. Tests in the longitudinal direction are not required on product tested in the transverse direction.

3.3.3.1.1.1 At Room Temperature:

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%

3.3.3.1.1.2 At 1000°F (540°C): Specimens shall be heated to 1000°F ± 10 (540°C ± 5) held at heat for 20 - 30 min., and tested in accordance with ASTM E21 at 1000°F ± 10 (540°C ± 5).

Tensile Strength, min	175,000 psi (1205 MPa)
Yield Strength at 0.2% Offset, min	135,000 psi (930 MPa)
Elongation in 4D, min	10%
Reduction of Area, min	35%

3.3.3.1.2 Transverse: Shall be as follows, determined on specimens selected and prepared in accordance with AMS 2310 from bars and forging stock over 25 to 256 sq in. (over 160 to 1650 cm^2), incl, in cross-sectional area.

Tensile Strength, min	260,000 psi (1795 MPa)
Yield Strength at 0.2% Offset, min	215,000 psi (1480 MPa)
Reduction of Area	

Section Size		Percent	
Square Inches	Square Centimetres	Minimum	Average
Over 25 to 75, excl	Over 160 to 485, excl	6	15
75 to 100, incl	485 to 645, incl	6	10
Over 100 to 150, incl	Over 645 to 970, incl	5	-
Over 150 to 225, incl	Over 970 to 1450, incl	4	-
Over 225 to 256, incl	Over 1450 to 1650, incl	3	-

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 of 3.3.3.1.1.1 or 3.3.3.1.2 are met.

3.3.3.3 Grain Size: Shall be as follows, determined in accordance with ASTM E112:

3.3.3.3.1 Bars and Forgings 2.50 in. (62.5 mm) and Under in Cross-Sectional Thickness: 7 or finer with occasional grains as large as 5 permissible.

3.3.3.3.2 Bars and Forgings Over 2.50 in. (62.5 mm) in Cross-Sectional Thickness: 5 or finer with occasional grains as large as 3 permissible.

3.4 Quality:

3.4.1 Steel shall be aircraft quality conforming to AMS 2301.

3.4.2 The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from internal and external 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 surfaces.

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.

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 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: Tests to determine conformance to the following requirements are classified as acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1), macrostructure (3.3.1), and AMS 2301 frequency-severity rating (3.4.1) of each heat.

4.2.1.2 Condition (3.2.1), decarburization (3.3.2), and tolerances (3.6) of each lot of bars.

4.2.1.3 Room-temperature longitudinal tensile properties (3.3.3.1.1.1), hardness (3.3.3.2), and grain size (3.3.3.3) of each lot of bars, forgings, and forging stock.

4.2.1.4 Room-temperature transverse tensile properties (3.3.3.1.2) of each lot of bars and forging stock.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for tensile properties at 1000°F (540°C) of bars, forgings, and forging stock are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed prior to or 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.

4.2.3.1 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:

4.3.1 Bars: AMS 2370.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 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.

4.4 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 three copies of a report showing the results of tests for chemical composition, macrostructure, and AMS 2301 frequency-severity rating of each heat and the results of tests on each lot to determine conformance to the other acceptance test requirements of this specification. This report shall include the purchase order number, heat number, AMS 6485E, nominal 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.