



AEROSPACE MATERIAL

Society of Automotive Engineers, Inc. SPECIFICATION

TWO PENNSYLVANIA PLAZA, NEW YORK, N. Y. 10001

AMS 6445B

Superseding AMS 6445A

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STEEL BARS, FORGINGS, AND TUBING

1.05Cr - 1.1Mn (0.92 - 1.02C) (Modified 51100)

Premium Quality, Consumable Electrode Vacuum Melted

1. SCOPE:

- 1.1 **Form:** This specification covers a premium-quality, low-alloy steel in the form of bars, forgings, mechanical tubing, and forging stock.
- 1.2 **Application:** Primarily for critical bearing components requiring a through-hardening steel usually with hardness of approximately 60 HRC and section thicknesses between 0.40 in. (10.16 mm) and 0.80 in. (20.32 mm) and subject to very rigid inspection standards.

2. **APPLICABLE DOCUMENTS:** The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specification (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 Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.

2.1.1 Aerospace Material Specifications:

AMS 2251 - Tolerances, 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 - Premium Aircraft Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
AMS 2350 - Standards and Test Methods
AMS 2370 - Quality Assurance Sampling of Carbon and Low Alloy Steels, Wrought Products Except Forgings
AMS 2372 - Quality Assurance Sampling of Carbon and Low Alloy Steels, Forgings and Forging Stock
AMS 2375 - Approval and Control of Critical Forgings
AMS 2808 - Identification, Forgings

2.1.2 Aerospace Standards:

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

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

ASTM A370 - Mechanical Testing of Steel Products
ASTM A604 - Macroetch Testing of Consumable Electrode Vacuum Arc Remelted Steel Bars and Billets
ASTM E45 - Determining the Inclusion Content of Steel
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

- 2.3 Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, Pennsylvania 19120.

2.3.1 Federal Standards:

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

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 approved analytical methods:

	min	max
Carbon	0.92	1.02
Manganese	0.95	1.25
Silicon	0.50	0.70
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	0.90	1.15
Nickel	--	0.25
Molybdenum	--	0.08
Copper	--	0.35

- 3.1.1 Check Analysis: Composition variations shall meet the requirements of AMS 2259, paragraph titled "Low Alloy Steels".

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

3.2.1 Bars:

- 3.2.1.1 Bars 0.500 In. (12.700 mm) and Under in Diameter or Distance Between Parallel Sides: Cold finished, with microstructure of spheroidized cementite in ferrite matrix, having tensile strength not higher than 120,000 psi (827 MN/m²) or equivalent hardness.

- 3.2.1.2 Bars Over 0.500 In. (12.700 mm) in Diameter or Distance Between Parallel Sides: Hot finished, with microstructure of spheroidized cementite in ferrite matrix, having hardness not higher than 207 HB or equivalent except that bars ordered cold finished may have hardness as high as 248 HB or equivalent.

- 3.2.2 Forgings: As ordered.

- 3.2.3 Mechanical Tubing: Cold finished with microstructure of spheroidized cementite in ferrite matrix having hardness not higher than 24 HRC or equivalent except that tubing ordered hot finished shall have hardness not higher than 95 HRB or equivalent.

- 3.2.4 Forging Stock: As ordered by the forging manufacturer.

- 3.3 Properties: Product shall conform to the following requirements; hardness testing shall be performed in accordance with ASTM A370.

- 3.3.1 Inclusion Rating: Steel from which the product is produced shall be subjected to the macrostructure test and to either the fracture or microscopic test as agreed upon by purchaser and vendor. In the event that agreement is not reached by purchaser and vendor, the microscopic test shall be performed.

3.3.1.1 Macrostructure: Visual examination of transverse sections of bars and forging stock, etched in accordance with ASTM A604 in hot hydrochloric acid (1:1) at 160 - 180 F (71.1 - 82.2 C) for sufficient time to develop a well-defined macrostructure, shall show no injurious imperfections such as pipe, internal cracks, porosity, segregation, and inclusions detrimental to fabrication or to performance of parts. Macrostructure shall be equal to or better than the macrographs of ASTM A604 agreed upon by purchaser and vendor.

3.3.1.2 Fracture: Specimens approximately 0.375 in. (9.525 mm) in thickness shall be normalized, annealed, hardened, and fractured through the approximate center of the cross section. Such specimens shall show no injurious imperfections such as pipe, excessive segregation, and porosity. The fractured surfaces shall show no nonmetallic streaks over 1/16 in. (1.6 mm) in length and not more than one nonmetallic streak 1/32 - 1/16 in. (0.8 - 1.6 mm) in length for each 10 sq in. (64.5 cm²) or fraction thereof of such surfaces.

3.3.1.3 Microscopic Test: Radial specimens, approximately 0.28 sq in. (1.8 cm²) in surface area cut mid-way between center and surface of hardened fracture samples, shall be polished on a face longitudinal to the direction of rolling, for microinclusion rating in accordance with the Jernkontoret chart, Method D, Plate III, of ASTM E45. No sample shall exceed the following limits:

Inclusion Type	Worst Field
A - Thin	2.0
A - Heavy	1.0
B - Thin	1.5
B - Heavy	1.0
C - Thin	1.5
C - Heavy	1.0
D - Thin	1.5
D - Heavy	1.0

3.3.1.3.1 For types A, B, and C thin combined, there shall be not more than three fields of No. 2.0 A type or No. 1.5 B and C types and not more than five other lower rateable A, B, and C type thin fields per specimen. For type D thin, there shall be not more than three No. 1.5 fields and no more than five other lower rateable type D thin fields per specimen. There shall be not more than one field each of No. 1.0 A, B, C, or D type heavy per specimen.

3.3.1.3.2 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 the Jernkontoret chart, Plate III, ASTM E45.

3.3.2 Decarburization:

3.3.2.1 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 3.3.2.4.

3.3.2.2 Allowable decarburization of bars, billets, and tubing ordered for redrawing or forging or to specified microstructural requirements other than spheroidized cementite in ferrite matrix shall be as agreed upon by purchaser and vendor.

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

TABLE I

Nominal Diameter or Distance Between Parallel Sides Inches	Depth of Decarburization Inch
Up to 0.50, incl	0.015
Over 0.50 to 1.00, incl	0.020
Over 1.00 to 1.50, incl	0.025
Over 1.50 to 2.00, incl	0.030
Over 2.00 to 2.50, incl	0.035
Over 2.50 to 3.00, incl	0.040
Over 3.00	0.045

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimeters	Depth of Decarburization Millimeters
Up to 12.70, incl	0.381
Over 12.70 to 25.40, incl	0.508
Over 25.40 to 38.10, incl	0.635
Over 38.10 to 50.80, incl	0.762
Over 50.80 to 63.50, incl	0.889
Over 63.50 to 76.20, incl	1.016
Over 76.20	1.143

- 3.3.2.4 Decarburization on the ID and OD of all tubing to which 3.3.2.1 or 3.3.2.2 is not applicable shall be not greater than 0.025 in. (0.635 mm).
- 3.3.2.5 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.
- 3.3.2.5.1 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 in. (0.127 mm) and width is 0.065 in. (1.651 mm) or less.
- 3.3.3 Response to Heat Treatment: Specimens shall be protected by suitable means or treated in a neutral atmosphere to minimize scaling and prevent either carburization or decarburization during heat treatment. The specimens shall be placed in a furnace which is at $1530\text{ F} \pm 15$ ($832.2\text{ C} \pm 8.3$), allowed to heat to $1530\text{ F} \pm 15$ ($832.2\text{ C} \pm 8.3$), held at heat for 30 min., and quenched in commercial paraffin oil (100 SUS at 100 F (37.8 C)) at room temperature. The hardened specimens shall have substantially uniform hardness not lower than 63 HRC at any point below any permissible decarburization.
- 3.4 Quality: Steel shall be premium quality conforming to AMS 2300; it shall be multiple melted using vacuum consumable electrode process in the remelt cycle. The product shall be uniform in quality and condition, clean, sound, and free from foreign materials and from internal and external imperfections detrimental to fabrication or to performance of parts.
- 3.4.1 Bars and tubing 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 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 values shown in AS 1182.
- 3.5 Sizes: Except when exact lengths or multiples of exact lengths are ordered, bars and tubing will be acceptable in mill lengths of 6 - 20 ft (1.8 - 6.1 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 shall conform to all applicable requirements of the following:
- 3.6.1 Bars: AMS 2251.
- 3.6.2 Mechanical Tubing: AMS 2253.
4. QUALITY ASSURANCE PROVISIONS:
- 4.1 Responsibility for Inspection: The vendor shall supply all samples 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 perform such confirmatory testing as he deems necessary to assure that the product conforms to the requirements of this specification.
- 4.2 Classification of Tests: Tests to determine conformance to all technical requirements of this specification are classified as routine tests.
- 4.3 Sampling: Shall be in accordance with the following; a heat shall be the consumable electrode remelted ingots produced from steel originally melted as a single furnace charge.
- 4.3.1 Bars and Mechanical Tubing: AMS 2370.
- 4.3.2 Forgings and Forging Stock: AMS 2372.
- 4.3.3 Specimens for inclusion rating (3.3.1) shall represent the full cross section of billet stock taken from the top and bottom of at least the first, middle, and last usable ingot of each heat. Samples for macro-structure testing (3.3.1.1) shall be full cross-sectional specimens obtained from the finished billet or a suitable rerolled product.
- 4.3.4 Specimens for response to heat treatment test (3.3.3) of bars shall be full cross section of the product ground on both faces normal to the axis so that length is 0.75 in. (19.05 mm). Specimens from mechanical tubing shall be full sections of the tubing, shall have wall thickness of 0.75 in. (19.05 mm) or less with wall thicknesses over 0.75 in. (19.05 mm) being turned to 0.75 in. (19.05 mm), and shall be ground on both faces normal to the axis so that length is 0.625 in. (15.875 mm).
- 4.4 Approval: When specified, approval and control of critical 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 of the results of tests for chemical composition, inclusion rating, response to heat treatment, and AMS 2300 frequency-severity rating of each heat in the shipment. This report shall include the purchase order number, heat number, material specification number and its revision letter, size, and quantity from each heat. If forgings are supplied, the part number and the size and source of stock used to make the forgings shall also be included.