

NOTICE OF
ADOPTION

ADOPTION NOTICE
20 December 1991
AMS 6411D
1 October 1990
SUPERSEDING
AMS 6411C
20 March 1985

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Title of Document: Steel Bars, Forgings, and Tubing
0.88Cr - 1.8Ni - 0.42Mo - 0.08V (0.28 - 0.33C)
Consumable Electrode Remelted

Date of Specific Issue Adopted: 1 October 1990

Releasing Non-Government Standards Body: SAE

Custodians:

Air Force - 11
Army - MR
Navy - AS

Military Coordinating Activity

Air Force - 11

(Project No: 9510-0826)

FSC 9510

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400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS-6411

REV
D

Issued 1969-05-01
Revised 1990-10-01

Superseding AMS-6411C

Submitted for recognition as an American National Standard

STEEL BARS, FORGINGS, AND TUBING
0.88Cr - 1.8Ni - 0.42Mo - 0.08V (0.28 - 0.33C)
Consumable Electrode Remelted

UNS K23080

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: Primarily for parts requiring high tensile strength and good ductility with relatively high impact strength, superior transverse properties, and hardness. Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking after heat treatment; ARP 1110 recommends practices to minimize such conditions.

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.

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2.1.1 Aerospace Material Specifications:

- 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
- MAM-2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
- AMS-2310 - Qualification Sampling of Steels, Transverse Tensile Properties
- 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-2806 - Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat Resistant Steels and Alloys
- AMS-2808 - Identification, Forgings

2.1.2 Aerospace Standards:

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

2.1.3 Aerospace Recommended Practices:

- ARP1110 - Minimizing Stress Corrosion Cracking in Heat Treatable Wrought Low Alloy and Martensitic Corrosion Resistant Steels

2.2 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

- ASTM A 255 - End-Quench Test for Hardenability of Steel
- ASTM A 370 - Mechanical Testing of Steel Products
- ASTM A 604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
- 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

2.3 U.S. Government Publications: Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.2.3.1 Military Standards:

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

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3. TECHNICAL REQUIREMENTS:

- 3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E 350, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	max
Carbon	0.28	0.33
Manganese	0.65	1.00
Silicon	0.15	0.35
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	0.75	1.00
Nickel	1.65	2.00
Molybdenum	0.35	0.50
Vanadium	0.05	0.10
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 A 370:

3.2.1 Bars:

- 3.2.1.1 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 130,000 psi (896 MPa) or hardness not higher than 29 HRC.

- 3.2.1.2 Bars Over 0.500 Inch (12.70 mm) in Nominal Diameter or Distance Between Parallel Sides: Hot finished, and annealed if necessary, having hardness not higher than 241 HB, or equivalent, except that bars ordered cold finished may have hardness as high as 248 HB, or equivalent.

- 3.2.2 Forgings: Normalized and tempered having hardness not higher than 269 HB, or equivalent.

- 3.2.3 Mechanical Tubing: Cold finished having hardness not higher than 25 HRC, or equivalent, except that tubing ordered hot finished and annealed shall have hardness not higher than 99 HRB, or equivalent.

- 3.2.4 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 A 370:

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- 3.3.1 Macrostructure: Visual examination of transverse sections as in 4.3.3 from bars, billets, tube rounds or tubes, and forging stock, etched in accordance with ASTM A 604 in hot hydrochloric acid, shall show no pipe or cracks. Except as specified in 3.3.1.1, 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 following macrographs of ASTM A 604; macrostructure standards for product over 36 square inches (232 cm²) in nominal cross-sectional area shall be as agreed upon by purchaser and vendor:

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

- 3.3.1.1 If tubes are produced directly from ingots or large blooms, transverse sections may be taken from tubes rather than tube rounds. Macrostructure standards for such tubes shall be as agreed upon by purchaser and vendor.

- 3.3.2 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, determined in accordance with ASTM E 112.

- 3.3.3 Hardenability: Shall be J49=14 minimum and J45=24 minimum, determined on the standard end-quench test specimen in accordance with ASTM A 255 except that the steel shall be normalized at 1700°F ± 10 (927°C ± 6) and the test specimen austenitized at 1550°F ± 10 (843°C ± 6). The hardenability test is not required on a product which will not yield a suitable specimen but the steel from which the product is made shall conform to the hardenability specified.

- 3.3.4 Decarburization:

- 3.3.4.1 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 II.

- 3.3.4.2 Allowable decarburization of bars, billets, and tube rounds or tubing ordered for redrawing or forging or to specified microstructural requirements shall be as agreed upon by purchaser and vendor.

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3.3.4.3 Decarburization of bars to which 3.3.4.1 or 3.3.4.2 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	0.015
Over 0.375 to 0.500, incl	0.017
Over 0.500 to 0.625, incl	0.019
Over 0.625 to 1.000, incl	0.022
Over 1.000 to 1.500, incl	0.025
Over 1.500 to 2.000, incl	0.030
Over 2.000 to 2.500, incl	0.035
Over 2.500 to 3.000, incl	0.040
Over 3.000 to 4.000, incl	0.045

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetres
Up to 9.52, incl	0.38
Over 9.52 to 12.70, incl	0.43
Over 12.70 to 15.88, incl	0.48
Over 15.88 to 25.40, incl	0.56
Over 25.40 to 38.10, incl	0.64
Over 38.10 to 50.80, incl	0.76
Over 50.80 to 63.50, incl	0.89
Over 63.50 to 76.20, incl	1.02
Over 76.20 to 101.60, incl	1.14

3.3.4.3.1 Limits for depth of decarburization of bars over 4.000 inches (101.60 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

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- 3.3.4.4 Decarburization of tubing to which 3.3.4.1 or 3.3.4.2 is not applicable shall be not greater than shown in Table II.

TABLE II

Nominal Wall Thickness Inch	Depth of Decarburization Inch	
	ID	OD
Up to 0.109, incl	0.008	0.015
Over 0.109 to 0.203, incl	0.010	0.020
Over 0.203 to 0.400, incl	0.012	0.025
Over 0.400 to 0.600, incl	0.015	0.030
Over 0.600 to 1.000, incl	0.017	0.035
Over 1.000	0.020	0.040

TABLE II (SI)

Nominal Wall Thickness Millimetres	Depth of Decarburization Millimetres	
	ID	OD
Up to 2.77, incl	0.20	0.38
Over 2.77 to 5.16, incl	0.25	0.51
Over 5.16 to 10.16, incl	0.30	0.64
Over 10.16 to 15.24, incl	0.38	0.76
Over 15.24 to 25.40, incl	0.43	0.89
Over 25.40	0.51	1.02

- 3.3.4.5 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.

- 3.3.4.5.1 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.

- 3.3.5 Response to Heat Treatment: Specimens shall meet the following requirements after being normalized by heating to $1700^{\circ}\text{F} \pm 10$ ($927^{\circ}\text{C} \pm 6$), holding at heat for not less than 1 hour, and cooling in air; hardened by heating to $1550^{\circ}\text{F} \pm 10$ ($843^{\circ}\text{C} \pm 6$), holding at heat for 1 hour ± 0.2 , and quenching in oil, and heated to the required tempering temperature, held at heat for not less than 1 hour, and cooled in air:

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3.3.5.1 Tensile Properties:

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

Tensile Strength, minimum	220,000 psi (1517 MPa)
Yield Strength at 0.2% Offset, minimum	185,000 psi (1276 MPa)
Elongation in 4D, minimum	10%
Reduction of Area, minimum	35%

- 3.3.5.1.2 Transverse: Shall be as follows, determined on specimens selected and prepared in accordance with AMS-2310; transverse tensile requirements of Table III are applicable only to product sufficiently large to yield tensile specimens not less than 2.50 inches (63.5 mm) in length.

TABLE III

Cross Sectional Area Square Inches	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi, min	Reduction of Area %, min	
			Average	Individual
Up to 144, incl	220,000	185,000	35	30
Over 144 to 225, incl	220,000	185,000	30	25
Over 225	220,000	185,000	25	20

TABLE III (SI)

Cross Sectional Area Square Centimetres	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Reduction of Area %, min	
			Average	Individual
Up to 929, incl	1517	1276	35	30
Over 929 to 1452, incl	1517	1276	30	25
Over 1452	1517	1276	25	20

3.4 Quality:

- 3.4.1 Steel shall be premium aircraft-quality conforming to AMS-2300 or MAM-2300 except that a maximum average frequency (F) rating of 0.10 and a maximum average severity (S) rating of 0.20 shall apply. Steel shall be multiple melted using consumable electrode process in the remelt cycle.
- 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 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 surfaces.