Society of Automotive Engineers, Inc.
TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE MATERIAL SPECIFICATION

AMS 6411A
Superseding AMS 6411

Issued 5-1-69
Revised 5-15-71

STEEL BARS, FORGINGS, AND TUBING
0.85Cr - 1.8Ni - 0.40Mo - 0.07V (0.28 - 0.33C)
Premium Quality, Consumable Electrode 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 parts requiring high tensile strength and good ductility with relatively high impact strength, superior transverse properties, and hardness.

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 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 Steel
AMS 2300 - Premium Aircraft Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
AMS 2310 - Steel, Transverse Strength and Ductility Requirements, Tensile Strength 260,000 psi, min
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 Steel Products

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

ASTM A255 - End-Quench Test for Hardenability of Steel
ASTM A370 - Mechanical Testing of Steel Products
ASTM A604 - Macroetching of Consumable Electrode Vacuum Arc Remelted Steel Bars and Billets
ASTM E23 - Notched Bar Impact Testing of Metallic Materials
ASTM E112 - Estimating Average Grain Size of Metals
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

Printed in U.S.A.

2.3 Government Publications: Available from Superintendent of Documents, Government Printing Office, Washington, D. C. 20402.

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	0.28	0.33
Manganese	0.75	1.00
Silicon	0.20	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 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. (12.7 mm) and Under in Diameter or Distance Between Parallel Sides: Cold finished having tensile strength not higher than 125,000 psi (862 MN/m^2).

3.2.1.2 Bars Over 0.500 In. (12.7 mm) in Diameter or Distance Between Parallel Sides: Hot finished, 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 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 A370:

3.3.1 Hardenability: Shall be J49=14 min and J45=24 min when determined on the standard end-quench test specimen in accordance with ASTM A255, except that the steel shall be normalized at 1700 F ± 10 (926.7 C ± 5.6) and the test specimen austenitized at 1550 F ± 10 (843.3 C ± 5.6). 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.

3.3.2 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, ASTM E112, McQuaid-Ehn test.

3.3.3 Macrostructure: Specimens shall be 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. Such specimens, when examined visually, 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.

3.3.4 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. Inside decarburization of such tubing shall not exceed the maximum depth specified in Table II.

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

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 Millimeters	Depth of Decarburization Millimeters
Up to 9.525, incl	0.381
Over 9.525 to 12.700, incl	0.432
Over 12.700 to 15.875, incl	0.473
Over 15.875 to 25.400, incl	0.559
Over 25.400 to 38.100, incl	0.635
Over 38.100 to 50.800, incl	0.762
Over 50.800 to 63.500, incl	0.889
Over 63.500 to 76.200, incl	1.016
Over 76.200 to 101.600, incl	1.143

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

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 Inches	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 Millimeters	Depth of Decarburization Millimeters	
	ID	OD
Up to 2.769, incl	0.203	0.381
Over 2.769 to 5.156, incl	0.254	0.508
Over 5.156 to 10.160, incl	0.305	0.635
Over 10.160 to 15.240, incl	0.381	0.762
Over 15.240 to 25.400, incl	0.432	0.889
Over 25.400	0.508	1.016

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 limits above by more than 0.005 in. (0.127 mm) and the width is 0.065 in. (1.651 mm) or less.

3.3.5 Properties After Heat Treatment: Specimens normalized by heating to 1700 F ± 10 (926.7 C ± 5.6), holding at heat for 1 hr, and cooling in air; hardened by heating to 1550 F ± 10 (843.3 C ± 5.6), holding at heat for 1 hr, and quenching in oil; and then held at the required tempering temperature for not less than 1 hr and cooled in air shall conform to the following requirements:

3.3.5.1 Tensile Properties:

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

Tensile Strength, min	220,000 psi (1517 MN/m^2)
Yield Strength at 0.2% Offset, min	185,000 psi (1276 MN/m^2)
Elongation in 2 in. (50.8 mm) or 4D, min	10%
Reduction of Area (round specimens), min	35%

3.3.5.1.2 Transverse Tensile Properties: Shall be as follows 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 test specimens not less than 2.50 in. (63.5 mm) in length:

TABLE III

Cross Section 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 Section Area Square Centimeters	Tensile Strength MN/m^2, min	Yield Strength at 0.2% Offset MN/m^2, min	Reduction of Area, %, min	
			Average	Individual
Up to 928.9, incl	1517	1276	35	30
Over 928.9 to 1451.5, incl	1517	1276	30	25
Over 1451.5	1517	1276	25	20

3.3.5.2 Impact Strength (Notch Sensitivity): The Izod impact value of transverse specimens heat treated in the same manner as tensile test specimens shall be not less than 15 ft-lb (20.3 N-m), determined in accordance with ASTM E23 at room temperature, using a V-notched specimen. Before heat treatment, specimens shall be to size or approximately to size, except for the notch.

3.4 Quality: Steel shall be premium quality conforming to AMS 2300 except that a maximum average frequency (F) rating of 0.10 and a maximum average severity (S) rating of 0.20 shall apply. Material shall be multiple melted using consumable electrode process in the remelt cycle, unless otherwise permitted. 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 injurious 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 shall 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 (3m).

3.6 Tolerances: Unless otherwise specified, tolerances shall conform to all applicable requirements of the following:

3.6.1 Bars: AMS 2251; for all hexagons, tolerances for cold finished shall apply.

3.6.2 Tubing: AMS 2253.