ADOPTION NOTICE

SAE-AMS6278, "STEEL BARS, FORGINGS, AND TUBING 4.1CR - 3.4NI - 4.2MO - 1.2V (0.11 - 0.15C) PREMIUM AIRCRAFT-QUALITY FOR BEARING APPLICATIONS DOUBLE VACUUM MELTED", was adopted on 20-DEC-91 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Commander, Defense Supply Center Philadelphia, ATTN: DSCP-ILEA, 700 Robbins Avenue, Philadelphia, PA 19111-5096. Copies of this document may be purchased from the Society of Automotive Engineers 400 Commonwealth Drive Warrendale, Pennsylvania, United States, 15096-0001. http://www.sae.org/

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AEROSPACE MATERIAL SPECIFICATION

SAE AMS-6278 REV A

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Submitted for recognition as an American National Standard

STEEL BARS, FORGINGS, AND TUBING
4.1Cr - 3.4Ni - 4.2Mo - 1.2V (0.11 - 0.15C)
Premium Aircraft-Quality for Bearing Applications
Double Vacuum Melted

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 critical carburized parts, such as bearings, operating under heavy loads and high speeds at moderate temperatures, 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 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.

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

21.1 (Cont'd.)

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-2750 - Pyrometry
AMS-2806 - Identification, Bars, Wire, Mechanical Tubing, and Extrusion, 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

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

ASTM A 370 - Mechanical Testing of Steel Products
ASTM A 604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E 45 - Determining the Inclusion Content of Steels
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

3. TECHNICAL REQUIREMENTS:

3.1 Ø Composition: Shall conform to the following percentages by weight, determined on specimens as in 4.3.3 by wet chemical methods in accordance with ASTM E 350, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	max
Carbon	0.11	0.15
Manganese	0.15	0.35
Silicon	0.10	0.25
Phosphorus	--	0.015
Sulfur	--	0.010
Chromium	4.00	4.25
Nickel	3.20	3.60
Molybdenum	4.00	4.50
Vanadium	1.13	1.33
Cobalt	--	0.25
Tungsten	--	0.15
Copper	--	0.10

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 Ø 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 125,000 psi (862 MPa) or hardness not higher than 27 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 having hardness not higher than 255 HB, or equivalent, except that bars ordered cold finished may have hardness as high as 269 HB, or equivalent.

3.2.2 Forgings: As ordered.

3.2.3 Mechanical Tubing: Cold finished having hardness not higher than 272 HB, or equivalent, except that tubing ordered hot finished and annealed shall have hardness not higher than 248 HB, 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 testing shall be performed in accordance with ASTM A 370:

3.3.1 Ø Macrostructure: Visual examination of transverse sections as in 4.3.4 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 cm^2) 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 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	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 Micro-Inclusion Rating: No specimen as in 4.3.5 shall exceed the following limits, determined in accordance with ASTM E 45, Method D:

	A		B		C		D	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
Worst Field Severity	1.5	1.0	1.0	1.0	1.0	1.0	1.5	1.0
Worst Field Frequency, maximum	*	1	*	1	*	1	3	1
Total Rateable Fields, Frequency, maximum	**	1	**	1	**	1	8	1

* Combined A+B+C; not more than 3 fields
** Combined A+B+C; not more than 8 fields

3.3.2.1 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 E 45.

3.3.3 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, determined by comparison of a polished and etched specimen with the chart in ASTM E 112.

3.3.4 Response to Heat Treatment: Specimens protected by suitable means or Ø treated in a neutral atmosphere or neutral salt to minimize scaling and prevent either carburization or decarburization, shall have average hardness not lower than 35 HRC after being heated to 2000° - 2025°F (1093° - 1107°C) by any convenient means, held to equalize at temperature, and either quenched into salt bath at 1100° - 1150°F (593° - 621°C), held in salt bath for 2 minutes ± 0.2, and air cooled to room temperature or directly air cooled to room temperature and tempered for 2 hours ± 0.25 at 975° - 1025°F (521° - 552°C). Pyrometry shall be in accordance with AMS-2750.

3.3.5 Decarburization:

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

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

3.3.5.3 Decarburization of bars to which 3.3.5.1 or 3.3.5.2 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 0.500, incl	0.015
Over 0.500 to 1.000, incl	0.030
Over 1.000 to 2.000, incl	0.040
Over 2.000 to 3.000, incl	0.050
Over 3.000 to 4.000, incl	0.065
Over 4.000 to 5.000, incl	0.095

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetres
Up to 12.70, incl	0.38
Over 12.70 to 25.40, incl	0.76
Over 25.40 to 50.80, incl	1.02
Over 50.80 to 76.20, incl	1.27
Over 76.20 to 101.60, incl	1.65
Over 101.60 to 127.00, incl	2.41

3.3.5.4 Decarburization of tubing to which 3.3.5.1 or 3.3.5.2 is not applicable shall be not greater than shown in Table II.

TABLE II

Nominal Outside Diameter Inches	Depth of Decarburization Inch
Up to 1.000, incl	0.025
Over 1.000 to 2.000, incl	0.035
Over 2.000 to 3.000, incl	0.045
Over 3.000 to 4.000, incl	0.055
Over 4.000 to 5.000, incl	0.080

TABLE II (SI)

Nominal Outside Diameter Millimetres	Depth of Decarburization Millimetres
Up to 25.40, incl	0.64
Over 25.40 to 50.80, incl	0.89
Over 50.80 to 76.20, incl	1.14
Over 76.20 to 101.60, incl	1.40
Over 101.60 to 127.00, incl	2.03

3.3.5.5 Limits for depth of decarburization of bars and tubing over 5.000 inches (127.00 mm) in nominal diameter, OD of tubing, or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.3.5.6 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.

3.3.5.6.1 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.

3.4 Quality:

3.4.1 Steel shall be premium aircraft-quality conforming to AMS-2300 or MAM-2300; it shall be double vacuum melted, using vacuum induction melting followed by vacuum arc consumable electrode remelting.

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.

3.4.3 Ø 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.

3.4.4 Ø Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of re-entrant grain flow.

3.5 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing will be acceptable in mill lengths of 6 - 20 feet (1.8 - 6.1 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).

3.6 Tolerances: Shall conform to all applicable requirements of the following:

3.6.1 Bars: AMS-2251 or MAM-2251.

3.6.2 Mechanical Tubing: AMS-2253 or MAM-2253.

4. QUALITY ASSURANCE PROVISIONS:

4.1 0 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. 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: Tests for all technical requirements are acceptance tests and shall be performed on each heat or lot as applicable.

4.3 0 Sampling and Testing: Shall be in accordance with the following; a heat shall be the consumable electrode remelted ingots produced from steel originally melted as a single vacuum induction 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 composition (3.1) shall represent the bottom of the first ingot and the top of the last ingot for complete analysis; in addition, carbon shall be determined on samples representing the top and bottom of all other ingots.

4.3.4 Ø Samples for macrostructure rating (3.3.1) 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 ingot of each heat. When ingot location is not available, the lot shall be sampled on at least one end of 10% of the bars or billets.