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400 Commonwealth Dr., Warrendale, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 6278

Issued 10-1-85
Revised

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 Aerospace Material Specifications and Aerospace Standards 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
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 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

2.1.1 (Cont'd.)

AMS 2375 - Control of Forgings Requiring First Article Approval
AMS 2806 - Identification, Bars, Wire, Mechanical Tubing, and Extrusion, 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 A604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E45 - Determining the Inclusion Content of Steels
ASTM E112 - Determining Average Grain Size
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 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, Ø determined on specimens as in 4.3.3 by wet chemical methods in accordance with ASTM E350 or by spectrographic or other analytical methods approved by 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; harndess 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 125,000 psi (860 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 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 A370:

3.3.1 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 E112.

3.3.2 Inclusion Rating: Shall be as follows:

3.3.2.1 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 A604 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. Except as specified in 3.3.2.1.1, porosity, segregation, inclusions, and other imperfections for product 36 sq in. (230 cm^2) and under in nominal cross-sectional area shall be no worse than the following macrographs of ASTM A604; macrostructure standards for product over 36 sq in. (230 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

3.3.2.1.1 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.

3.3.2.2 Micro-Inclusion Rating: No specimen as in 4.3.5 shall exceed the following limits, determined in accordance with ASTM E45, Method D:

Type	Inclusion Rating			
	A	B	C	D
Thin	1.5	1.0	1.0	1.5
Heavy	1.0	1.0	1.0	1.0

3.3.2.2.1 For types A, B, and C thin combined, there shall be not more than three fields of No. 1.5 A type or No. 1.0 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 D type 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.

3.3.2.3.2 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.

3.3.3 Response to Heat Treatment: Specimens protected by suitable means or 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 (1095° - 1105°C) by any convenient means, held to equalize at temperature, and either quenched into salt bath at 1100° - 1150°F (590° - 620°C), held in salt bath for 2 min. ± 0.2, and air cooled to room temperature or directly air cooled to room temperature and tempered for 2 hr ± 0.25 at 975° - 1025°F (525° - 550°C).

3.3.4 Decarburization:

3.3.4.1 Bars and tubing ordered ground, turned, or polished shall be free from decarburization on the gound, 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 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 0.500, 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 12.50, incl	0.38
Over 12.50 to 25.00, incl	0.75
Over 25.00 to 50.00, incl	1.00
Over 50.00 to 75.00, incl	1.25
Over 75.00 to 100.00, incl	1.65
Over 100.00 to 125.00, incl	2.40

3.3.4.4 Decarburization of all 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 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 25.00, incl	0.62
Over 25.00 to 50.00, incl	0.88
Over 50.00 to 75.00, incl	1.12
Over 75.00 to 100.00, incl	1.40
Over 100.00 to 127.00, incl	2.00

3.3.4.5 Limits for depth of decarburization of bars and tubing over 5.000 in. (125.00 mm) in nominal diameter (OD of tubing) or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.3.4.6 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.

3.3.6.1 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 in. (0.12 mm) and the width is 0.065 in. (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.

3.4.2.1 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.

3.4.2.2 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 and tubing 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: 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 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 4.4. 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 all technical requirements of this specification are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 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, processing, or both requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.2.1 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, 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 Samples for macrostructure (3.3.2.1) rating 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.

4.3.5 Samples for micro-inclusion rating (3.3.2.2) shall consist of not less than six specimens obtained from the full cross-section of billet stock taken from the top and bottom of at least the first, middle, and last usable ingots from each heat.

4.3.6 Samples for response to heat treatment (3.3.3) shall be as follows:

4.3.6.1 Specimens from bars shall be full cross-sections of the bar, ground on both faces normal to the axis so that length is 0.500 in. ± 0.010 (12.50 mm ± 0.25).

4.3.6.2 Specimens from mechanical tubing shall be full cross-sections of the tubing, shall have wall thickness not over 0.625 in. (16 mm) with wall thicknesses over 0.625 in. (16 mm) being turned to 0.625 in. ± 0.010 (16.00 mm ± 0.25), and shall be ground on both faces so that length is 0.500 in. ± 0.010 (12.50 mm ± 0.25).

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 a report showing the results of tests for chemical composition, grain size, inclusion rating, and frequency-severity cleanliness rating of each heat and for response to heat treatment of each lot. This report shall include the purchase order number, heat number, AMS 5847, 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.

4.5.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 5847, material specification number, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms, or copies of laboratory reports showing the results of tests to determine conformance.

4.6 Resampling and Retesting: Shall be in accordance wih the following:

4.6.1 Bars and Mechanical Tubing: AMS 2370.

4.6.2 Forgings and Forging Stock: AMS 2372.