

STEEL BARS, FORGINGS, AND TUBING
1.4Mn - 1.5Si - 0.30Cr - 1.8Ni - 0.40Mo (0.23 - 0.28C)
Consumable Vacuum Electrode Remelted

UNS K32550

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 parts requiring a through-hardening steel capable of developing a combination of high tensile strength, ductility, and fracture toughness, the parts being subject to rigid magnetic particle inspection standards. Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking after heat treatment; ARP1110 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 documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

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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 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
- AMS 2375 - Control of Forgings Requiring First Article Approval
- 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 Quality Steel Products

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.

- ASTM A370 - Mechanical Testing of Steel Products
- ASTM A604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
- ASTM E112 - Determining Average Grain Size
- ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
- ASTM E399 - Plane-Strain Fracture Toughness of Metallic Materials

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

2.3.2 Military Specification:

MIL-H-6875 - Heat Treatment of Steel, Process for

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 spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	max
Carbon	0.23	0.28
Manganese	1.20	1.50
Silicon	1.30	1.70
Phosphorus	--	0.010
Sulfur	--	0.010
Chromium	0.20	0.40
Nickel	1.65	2.00
Molybdenum	0.35	0.45
Copper	--	0.35

3.1.1 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2259, except that check analysis limits for carbon shall apply to over maximum only.

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

3.2.1 Bars:

3.2.1 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 145,000 psi (1000 MPa).

3.2.1.2 Bars Over 0.500 Inch (12.70 mm) in Nominal Diameter or Distance Between Parallel Sides: Hot finished, annealed if necessary, having hardness not higher than 293 HB, or equivalent, except that bars ordered cold finished may have hardness as high as 311 HB, or equivalent.

3.2.2 Forgings: Normalized and tempered in accordance with MIL-H-6875 to a hardness not higher than 311 HB, or equivalent.

3.2.3 Mechanical Tubing: Cold finished having hardness not higher than 32 HRC, or equivalent, except that tubing ordered hot finished and annealed shall have hardness not higher than 31 HRC, 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 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 A604, 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 A604; 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: Predominately 5 or finer with occasional grains as large as 3 permissible, determined in accordance with ASTM E112.

3.3.3 Decarburization:

3.3.3.1 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.

3.3.3.2 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.

3.3.3.3 Decarburization of bars to which 3.3.3.1 or 3.3.3.2 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 5.000, 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 127.00, incl	1.14

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

3.3.3.4 Decarburization of tubing to which 3.3.3.1 or 3.3.3.2 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 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

3.3.3.5 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.

3.3.3.5.1 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.

3.3.4 Response to Heat Treatment: Specimens shall have the following properties after being normalized by heating to 1725°F ± 25 (941°C ± 15), holding at heat for 60 minutes ± 5 and cooling in air; hardened by heating to 1600°F ± 25 (871°C ± 15), holding at heat for 60 minutes ± 5, and quenching in oil, and tempered by heating to 550°F ± 10 (288°C ± 5), holding at heat for 2 - 3 hours, and cooling in air at room temperature:

3.3.4.1 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, 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	30%

3.3.4.2 Transverse Tensile Properties: Shall be as shown in Table III, determined on specimens selected and prepared in accordance with AMS 2310; transverse tensile property requirements of Table III apply only to product from which tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken. Tensile property requirements for product over 225 square inches (1452 cm²) in cross-sectional area shall be as agreed upon by purchaser and vendor.

TABLE III

Nominal Cross-Sectional Area Square Inches	Tensile Strength psi, minimum	Yield Strength at 0.2% Offset psi, minimum	Reduction of Area %, minimum	
			Average	Individual
Up to 100, incl	220,000	185,000	30	25
Over 100 to 144, incl	220,000	185,000	25	20
Over 144 to 225, incl	220,000	185,000	20	15

TABLE III (SI)

Nominal Cross-Sectional Area Square Centimetres	Tensile Strength MPa, minimum	Yield Strength at 0.2% Offset MPa, minimum	Reduction of Area %, minimum	
			Average	Individual
Up to 645, incl	1517	1276	30	25
Over 645 to 929, incl	1517	1276	25	20
Over 929 to 1452, incl	1517	1276	20	15

3.3.4.3 Fracture Toughness:

3.3.4.3.1 Bars: When specified, shall be not lower than 100,000 psi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$), K_{Ic} or K_Q , determined in accordance with ASTM E399 on specimens in the LS (preferred) or LT orientation from bars 1.50 inch (38.1 mm) and over in section thickness and 4.0 inches (102 mm) and over wide. Fracture toughness and method of testing shall be as agreed upon by purchaser and vendor for bars under 1.50 inches (38.1 mm) in section thickness or under 4.0 inches (102 mm) wide.

3.3.4.3.2 Forgings: When specified, shall be not lower than 100,000 psi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$), K_{Ic} or K_Q , determined in accordance with ASTM E399 on specimens in TL orientation from forgings 1.50 inches (38.1 mm) and over in section thickness. Fracture toughness and method of testing shall be as agreed upon by purchaser and vendor for forgings under 1.50 inches (38.1 mm) in nominal thickness.

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 vacuum electrode practice in the last 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 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 AS1182.

3.4.3 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 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 4.5. 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 requirements for composition (3.1), condition (3.2), macrostructure (3.3.1), grain size (3.3.2), decarburization (3.3.3), response to heat treatment (3.3.4), quality (3.4), grain flow of die forgings (3.4.3), and tolerances (3.6) are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for fracture toughness (3.3.4.3) and frequency-severity cleanliness rating (3.4.1) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 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 and/or processing require reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.3.1 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, contracting officer, or 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 furnace charge:

4.3.1 A lot shall be all product from one heat processed to the same nominal size and shape at the same time.