



AEROSPACE MATERIAL SPECIFICATION

AMS6425

REV. D

Issued 1989-07
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Superseding AMS6425C

Steel, Bars, Forgings, and Tubing
1.4Mn - 1.5Si - 0.30Cr - 1.8Ni - 0.40Mo (0.23 - 0.28C)
Consumable Electrode Vacuum Melted
(Composition similar to UNS K32550)

RATIONALE

AMS6425D results from a Five Year Review and update of this specification and revises macrostructure, decarburization and reporting.

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

These products have been used typically for parts requiring a through-hardening steel capable of developing a combination of high tensile strength, ductility, and fracture toughness, but usage is not limited to such applications.

1.2.1 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 issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2251 Tolerances, Low-Alloy Steel Bars

AMS2253 Tolerances, Carbon and Alloy Steel Tubing

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AMS2259	Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
AMS2300	Steel Cleanliness, Premium Aircraft-Quality Magnetic Particle Inspection Procedure
AMS2310	Qualification Sampling and Testing of Steels for Transverse Tensile Properties
AMS2370	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Wrought Products and Forging Stock
AMS2372	Quality Assurance Sampling and Testing Carbon and Low-Alloy Steel Forgings
AMS2806	Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS2808	Identification Forgings
AS1182	Standard Stock Removal Allowance Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing
ARP1110	Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

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 E384	Knoop and Vickers Hardness of Materials
ASTM E399	Plane-Strain Fracture Toughness of Metallic Materials

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E350, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	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 AMS2259, except that check analysis limits for carbon shall apply to over maximum only.

3.2 Melting Practice

Steel shall be multiple melted using consumable electrode vacuum practice in the remelt cycles.

3.3 Condition

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

3.3.1 Bars

Bar shall not be cut from plate.

3.3.1.1 Bars 0.500 Inch (12.70 mm) and Under in Nominal Diameter or Least Distance Between Parallel Sides

Cold finished having tensile strength not higher than 145 ksi (1000 MPa) or equivalent hardness (See 8.2).

3.3.1.2 Bars Over 0.500 Inch (12.70 mm) in Nominal Diameter or Least Distance Between Parallel Sides

Hot finished, unless otherwise ordered, annealed if necessary, having hardness not higher than 293 HB, or equivalent (See 8.3). Bars ordered cold finished may have hardness as high as 311 HB, or equivalent.

3.3.2 Forgings

Normalized and tempered having hardness not higher than 311 HB, or equivalent (See 8.3).

3.3.3 Mechanical Tubing

Cold finished, unless otherwise ordered, having hardness not higher than 32 HRC, or equivalent (See 8.3). Tubing ordered hot finished and annealed shall have hardness not higher than 31 HRC, or equivalent.

3.3.4 Forging Stock

As ordered by the forging manufacturer.

3.4 Properties

The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A370:

3.4.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, tube rounds, and forging stock, etched in hot hydrochloric acid in accordance with ASTM A604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A604 shown in Table 2.

Table 2 - Macrostructure limits

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

3.4.2 Average Grain Size of Bar, Forgings, and Tubing

Shall be ASTM No. 5 or finer, determined in accordance with ASTM E112.

3.4.3 Decarburization

3.4.3.1 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 4.

3.4.3.2 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 producer.

3.4.3.3 Decarburization of bars that 3.4.3.1 or 3.4.3.2 is not applicable shall be not greater than shown in Table 3.

Table 3A - Maximum total depth of decarburization, bars, inch/pound units

Nominal Diameter or Distance Between Parallel Sides Inches	Total 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 3B - Maximum total depth of decarburization, bars, SI units

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
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

3.4.3.4 Decarburization of tubing that 3.4.3.1 or 3.4.3.2 is not applicable shall be not greater than shown in Table 4.

Table 4A - Maximum total depth of decarburization, tubing, inch/pound units

Nominal Wall Thickness Inches	Total Depth ID	Total Depth OD
	Inch	Inch
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 4B - Maximum total depth of decarburization, tubing, SI units

Nominal Wall Thickness Millimeters	Total Depth ID Millimeter	Total Depth OD Millimeters
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

3.4.3.5 Decarburization shall be evaluated by one of the two methods of 3.4.3.5.1 or 3.4.3.5.2.

3.4.3.5.1 Metallographic Method

A cross section taken perpendicular to the surface shall be prepared, etched, and visually examined metallographically at a magnification not to exceed 100X. Optical indications of decarburization (including complete decarburization [ferrite] plus partial decarburization) shall not exceed the limits of Tables 3 and 4.

3.4.3.5.2 Hardness Traverse Method

The total depth of decarburization shall be determined by a traverse method using microhardness testing in accordance with ASTM E384, at a magnification not exceeding 100X, conducted on a hardened but untempered specimen protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization is defined as the perpendicular distance from the surface to the depth under that surface where there is not further increase in hardness. Such measurements shall be far enough away from any adjacent surface to be uninfluenced by any decarburization on the adjacent surface. Acceptance shall be as listed in Tables 3 and 4.

3.4.3.5.2.1 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 inches (1.65 mm) or less.

3.4.3.6 In case of dispute, the total depth of decarburization determined using the microhardness traverse method shall govern.

3.4.4 Response to Heat Treatment of Bar, Forgings, and Tubing

Specimens shall have the following properties after being normalized by heating to 1725 °F ± 25 (941 °C ± 14), holding at heat for 1 hour per inch (25 mm) of maximum cross-section, and cooling at a rate equivalent to air cooling, hardened by heating to 1600 °F ± 25 (871 °C ± 14), holding at heat for 1 hour per inch (25 mm) of maximum cross-section, and quenching in oil, and tempered by heating to 550 °F ± 10 (288 °C ± 6), holding at heat for 2 to 3 hours, and cooling in air to room temperature:

3.4.4.1 Longitudinal Tensile Properties

Shall be as specified in Table 5; testing in the longitudinal direction need not be performed on product tested in the transverse direction.

Table 5 - Minimum longitudinal tensile properties

Property	Value
Tensile Strength	220 ksi (1517 MPa)
Yield Strength at 0.2% Offset	185 ksi (1276 MPa)
Elongation in 4D	10%
Reduction of Area	30%

3.4.4.2 Transverse Tensile Properties

Shall be as shown in Table 6, determined on specimens selected and prepared in accordance with AMS2310; transverse properties apply only to product from which tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken.

Table 6A - Minimum transverse tensile properties, inch/pound units

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

Table 6B - Minimum transverse tensile properties, SI UNITS

Nominal Cross-Sectional Area Square Centimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Reduction of Area % Average	Reduction of Area % 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

3.4.4.3 Fracture Toughness

When specified, bars and/or forgings shall be subjected to fracture toughness testing as follows:

3.4.4.3.1 Bars

Shall be not lower than 100 ksi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$), K_{IC} or K_{IQ} , determined in accordance with ASTM E399 on specimens in the LS (preferred) or LT orientation from bars 1.50 inches (38.1 mm) and over in section thickness and 4.0 inches (102 mm) and over wide.

3.4.4.3.2 Forgings

Shall be not lower than 100 ksi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$), K_{IC} or K_{IQ} , determined in accordance with ASTM E399 on specimens in the TL orientation from forgings 1.50 inches (38.1 mm) and over in section thickness.

3.5 Quality

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.

3.5.1 Steel shall be premium aircraft-quality conforming to AMS2300 except that a maximum average frequency (F) rating of 0.10 and a maximum average severity (S) rating of 0.20 shall apply.

3.5.2 Bars and tubing ordered hot rolled or cold drawn, or ground, turned, or polished shall, after removal of the standard stock removal allowance in accordance with AS1182, be free from seams, laps, tears, and cracks open to the machined, ground, turned, or polished surface.

3.5.3 Grain flow of die forgings, except in areas that contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.6 Tolerances

3.6.1 Bars

In accordance with AMS2251.

3.6.2 Mechanical Tubing

In accordance with AMS2253.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), condition (3.3), macrostructure (3.4.1), average grain size (3.4.2), decarburization (3.4.3), response to heat treatment (3.4.4), fracture toughness when specified (3.4.4.3), and tolerances (3.6) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Frequency-severity cleanliness rating (3.5.1) and grain flow of die forgings (3.5.3) are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

4.3.1 Bars, Mechanical Tubing, and Forging Stock

In accordance with AMS2370.

4.3.2 Forgings

In accordance with AMS2372.

4.4 Reports

4.4.1 The producer of bars, forgings, and tubing shall furnish with each shipment a report showing the producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), the results of tests for composition, macrostructure, and response to heat treatment for each heat, and for average grain size and condition of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS6425D, product form and size (and/or part number, if applicable), and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.4.2 Report the nominal metallurgically worked cross sectional size and the cut size, if different (See 3.3.1).

4.4.3 The producer of forging stock shall furnish with each shipment a report showing the producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), the results of tests for composition, and macrostructure for each heat and the results of any additional property requirements imposed by 8.6. This report shall include the purchase order number, heat number, AMS6425D, size and quantity.