SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS6525 | REV. D

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Superseding AMS6525C

Steel, Bars, Forgings, Tubing, and Rings
0.75Cr - 9.0Ni - 4.5Co - 1.0Mo - 0.09V (0.17 - 0.23C)
Consumable Electrode Vacuum Melted
(Composition similar to UNS K91472)

RATIONALE

AMS6525D results from a Five Year Review and update of this specification.

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality, low-alloy steel in the form of bars, forgings, mechanical tubing, flash welded rings, and stock for forging or flash welded rings.

1.2 Application

These products have been used typically for heat-treated parts requiring toughness and through-hardening to high strength levels and where such parts may require welding during fabrication, but usage is not limited to such applications.

1.2.1 Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; 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 724-776-4970 (outside USA), www.sae.org

AMS2251 Tolerances, Low-Alloy Steel Bars

AMS2253 Tolerances, Carbon and Alloy Steel Tubing

AMS2259 Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS6525D

AMS2300 Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure

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

AMS2750 Pyrometry

AMS2806 Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys

AMS2808 Identification, Forgings

AMS7496 Rings, Flash Welded, Carbon and Low-Alloy Steels

AS1182 Standard Stock Removal Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

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 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 Steel

ASTM E 112 Determining Average Grain Size

ASTM E 353 Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

ASTM E 384 Knoop and Vickers Hardness of Materials

ASTM E 399 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 E 353, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Carbon	0.17	0.23
Manganese	0.20	0.40
Silicon	--	0.20
Phosphorus	--	0.010
Sulfur	--	0.010
Chromium	0.65	0.85
Nickel	8.50	9.50
Cobalt	4.25	4.75
Molybdenum	0.90	1.10
Vanadium	0.06	0.12
Copper	--	0.35

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Melting Practice

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

3.3 Condition

The product shall be supplied in the following condition; hardness and tensile strength shall be determined in accordance with ASTM A 370.

3.3.1 Bars

Bar shall not be cut from plate. (Also see 4.4.2.)

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

Annealed, or normalized and tempered, and cold finished having tensile strength not higher than 180 ksi (1241 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, annealed, or normalized and tempered, and descaled, having hardness not higher than 341 HB, or equivalent (See 8.3). Bars ordered annealed and cold finished may have hardness as high as 352 HB, or equivalent.

3.3.2 Forgings and Flash Welded Rings

Annealed, or normalized and tempered, in accordance with 3.4, and descaled having hardness not higher than 352 HB, or equivalent (See 8.3).

3.3.2.1 Flash welded rings shall not be supplied unless specified or permitted on purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS7496.

3.3.3 Mechanical Tubing

Annealed, or normalized and tempered, and cold finished having hardness not higher than 38 HRC, or equivalent (See 8.3). Tubing ordered hot finished and annealed shall have hardness not higher than 36 HRC, or equivalent (See 8.3).

3.3.4 Stock for Forging or Flash Welded Rings

As ordered by the forging or flash welded ring manufacturer.

3.4 Heat Treatment

Bars, forgings, mechanical tubing, and flash welded rings shall be annealed by heating to 1250 °F ± 25 (677 °C ± 14), holding at heat for 4 hours ± 0.25, cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool, reheating to 1150 °F ± 25 (621 °C ± 14), holding at heat for 4 hours ± 0.25, and cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool. Pyrometry shall be in accordance with AMS2750.

3.4.1 When specified by purchaser, the product shall be normalized prior to annealing by heating to 1650 °F ± 25 (899 °C ± 14), holding at heat for not less than 1 hour per inch (25 mm) of maximum thickness but not less than 1 hour, and cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool.

3.5 Properties

The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A 370:

3.5.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, tube rounds, and stock for forging or flash welded rings, etched in hot hydrochloric acid in accordance with ASTM A 604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A 604 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

3.5.1.1 Macrostructure examination is not required for hollow tubes that are produced directly from ingots or blooms unless specified by purchaser, in which case the purchaser shall specify standards to be used.

3.5.2 Micro-Inclusion Rating of Each Heat

No specimen shall exceed the limits shown in Table 3, determined in accordance with ASTM E 45, Method D.

TABLE 3 - MICRO-INCLUSION LIMITS

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

a - Combined A+B+C, not more than 3 fields

b - Combined A+B+C, not more than 8 fields

3.5.2.1 A rateable field is defined as one which has a type A, B, C, or D inclusion rating of at least 1.0 thin or heavy in accordance with the Jernkontoret Chart, Plate I-r, ASTM E 45.

3.5.3 Average Grain Size of Bars, Forgings, Tubing and Flash Welded Rings

Shall be ASTM No. 5 or finer, determined in accordance with ASTM E 112.

3.5.4 Decarburization

3.5.4.1 Bars, tubing, and flash welded rings 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 5.

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

3.5.4.3 Decarburization of bars and flash welded rings to which 3.5.4.1 or 3.5.4.2 is not applicable shall be not greater than shown in Table 4.

TABLE 4A - MAXIMUM TOTAL DEPTH OF DECARBURIZATION, INCH/POUND UNITS

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inch
Up to 0.375, incl	0.010
Over 0.375 to 0.500, incl	0.012
Over 0.500 to 0.625, incl	0.014
Over 0.625 to 1.000, incl	0.017
Over 1.000 to 1.500, incl	0.020
Over 1.500 to 2.000, incl	0.025
Over 2.000 to 2.500, incl	0.030
Over 2.500 to 3.000, incl	0.035
Over 3.000 to 5.000, incl	0.045

TABLE 4B - MAXIMUM TOTAL DEPTH OF DECARBURIZATION, SI UNITS

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
Up to 9.52, Incl	0.25
Over 9.52 to 12.70, incl	0.30
Over 12.70 to 15.88, incl	0.36
Over 15.88 to 25.40, incl	0.43
Over 25.40 to 38.10, incl	0.51
Over 38.10 to 50.80, incl	0.64
Over 50.80 to 63.50, incl	0.76
Over 63.50 to 76.20, incl	0.89
Over 76.20 to 127.00, incl	1.14

3.5.4.4 Decarburization of tubing to which 3.5.4.1 or 3.5.4.2 is not applicable shall be not greater than shown in Table 5.

TABLE 5A - MAXIMUM TOTAL DEPTH OF DECARBURIZATION, INCH/POUND UNITS

Nominal Wall Thickness Inches	Total Depth ID Inch	Total Depth OD 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 5B - MAXIMUM TOTAL DEPTH OF DECARBURIZATION, 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

3.5.4.5 Depth of decarburization on forgings shall be not greater than 0.060 inch (1.52 mm); forgings shall show no carburization.

3.5.4.6 Decarburization shall be measured by the metallographic method, by the HR30N scale hardness testing method, or by a traverse method using microhardness testing in accordance with ASTM E 384. The hardness method(s) shall be conducted on a hardened but untempered specimen 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 on the adjacent surface. In case of dispute, the depth of decarburization determined using the microhardness traverse method shall govern.

3.5.4.6.1 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.

3.5.5 Response to Heat Treatment

Specimens, taken from product 100 square inches (645 cm^2) and under in cross-sectional area after heat treatment as in 3.5.5.1, shall meet the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4.

3.5.5.1 Heat Treatment

3.5.5.1.1 Normalizing

Heat to 1650 °F ± 25 (899 °C ± 14), hold at heat for 1 hour per inch (25.4 mm) of maximum cross-section, and cool to room temperature at a rate equivalent to air cooling.

3.5.5.1.1.1 Normalizing may be omitted if the product was supplied normalized and annealed.

3.5.5.1.2 Hardening

Heat to 1525 °F ± 25 (829 °C ± 14), hold at heat for 1 hour per inch (25 mm) of maximum section thickness but not less than 1 hour, and quench in oil at 60 to 150 °F (16 to 66 °C), cool within 2 hours to -100 °F ± 25 (-73 °C ± 14), hold at -100 °F ± 25 (-73 °C ± 14) for not less than 1 hour, and warm to room temperature.

3.5.5.1.3 Tempering

Heat to 1050 °F ± 25 (566 °C ± 14), hold at heat for not less than 4 hours, and cool in air to room temperature.

3.5.5.2 Tensile Properties

Shall be as shown in Table 6.

TABLE 6 - MINIMUM TENSILE PROPERTIES

Property	Value
Tensile Strength	190 ksi (1310 MPa)
Yield Strength at 0.2% Offset	180 ksi (1241 MPa)
Elongation in 4D	12%
Reduction of Area	45%

3.5.5.3 Hardness

Shall be 41 to 45 HRC, or equivalent (See 8.3).

3.5.5.4 Fracture Toughness

Fracture toughness, when specified, shall be not less than 110 $\sqrt{\text{inch}}$ ksi (121 $\sqrt{\text{m}}$ MPa) K_{IC} or K_Q, determined in accordance with ASTM E 399 on any product form that a specimen of a standardized ASTM E 399 orientation can be extracted having dimensions not less than 1.50 inches (38.1 mm) in section thickness and not less than 4.00 inches (101.6 mm) in width.

3.5.6 Forging Stock

Specimens extracted from a forged down test coupon heat treated as in 3.5.5.1 shall conform to the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4. If specimens taken from the unforged stock after heat treatment as in 3.5.5.1 conform to the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.6.1 Forging stock from a heat meeting the requirements of 3.5.6 in one size need not be retested for use in a smaller size.

3.5.7 Stock for Flash Welded Rings

Specimens taken from the stock after heat treatment as in 3.5.5.1 shall conform to the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4.

3.6 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.

3.6.1 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.

3.6.2 Bars, tubing, and flash welded rings ordered hot rolled or cold drawn, 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 ground, turned, or polished surface.

3.6.3 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.

3.7 Tolerances

3.7.1 Bars

In accordance with AMS2251.

3.7.2 Mechanical Tubing

In accordance with AMS2253.