AEROSPACE MATERIAL SPECIFICATION

AMS6515™	REV. C
Issued 2008-02 Revised 2023-11 Superseding AMS6515B	

(R) Steel, Maraging, Bars, Forgings, Mechanical Tubing, Rings, and Stock for Forgings and Rings
18.5Ni - 12.0Co - 4.9Mo - 1.40Ti - 0.10Al
Premium Aircraft Quality
Double Vacuum Melted, Annealed (Maraging 350)
(Composition similar to UNS K93540)

RATIONALE

AMS6515C is the result of a Five-Year Review and update of the document. The revision updates the Title and Scope consistent with similar specifications (see 1.1 and 1.2), revises composition testing and reporting requirements (see 3.1.1 and 3.1.2), clarifies melting practice (see 3.2), updates prohibition on unauthorized exceptions (see 3.5.5.1.2, 4.4.4, and 8.6), updates heat-treatment control (see 3.4), updates macrostructure requirements (see 3.5.1 and 8.7), revises micro-inclusion rate method requirements (see 3.5.2), addresses options on forging stock testing (see 3.5.6.1), and adds a note on use of AS1182 (see 8.5).

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality steel in the form of bars, forgings, mechanical tubing, and flash-welded rings up to 5.000 inches (127.00 mm), inclusive, in diameter or least distance between parallel sides, and stock of any size for forging or flash-welded rings.

1.2 Application

These products have been used typically for parts requiring through-hardening, without liquid quenching, to a minimum yield strength of 330 ksi (2275 MPa) and where such parts may require welding during fabrication, but usage is not limited to such applications.

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.

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS6515C

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.

AMS2248 Chemical Check Analysis Limits, Corrosion- and Heat-Resistant Steels and Alloys, Maraging and Other Highly Alloyed Steels, and Iron Alloys

AMS2251 Tolerances, Low-Alloy Steel Bars

AMS2253 Tolerances, Carbon and Alloy Steel Tubing

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

AMS2761 Heat Treatment of Steel Raw Materials

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

AS7766 Terms Used in Aerospace Metals Specifications

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 A751 Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

ASTM E45 Determining the Inclusion Content of Steel

ASTM E112 Determining Average Grain Size

ASTM E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

2.3 U.S. GOVERNMENT PUBLICATIONS

Copies of these documents are available online at https://quicksearch.dla.mil.

MIL-S-46850 Steel: Bar, Plate, Sheet, Strip , Forgings, And Extrusions , 18 Percent Nickel Alloy, Maraging, 200 Ksi, 250 Ksi, 300 Ksi, And 350 Ksi, High Quality

2.4 Definitions

Terms used in AMS are defined in AS7766.

3. TECHNICAL REQUIREMENTS

3.1 Composition

Composition shall conform to the percentages by weight shown in Table 1, determined in accordance with ASTM A751 or by other analytical methods acceptable to the purchaser.

Table 1 - Composition

Element	Min	Max
Carbon	--	0.03
Manganese	--	0.10
Silicon	--	0.10
Phosphorus	--	0.010
Sulfur	--	0.010
Nickel	18.00	19.00
Cobalt	11.50	12.50
Molybdenum	4.60	5.20
Titanium	1.30	1.60
Aluminum	0.05	0.15
Chromium	--	0.50
Copper	--	0.50

3.1.1 Any additions of calcium, zirconium, and boron shall be made prior to pouring the first melt into electrodes; these elements shall not exceed 0.05% calcium, 0.02% zirconium, and 0.003% boron, but analysis for these elements need not be made.

3.1.2 The producer may test for any element not listed in Table 1 or 3.1.1 and include this analysis in the report of 4.4. Reporting of any element not listed in the composition table is not a basis for rejection unless limits of acceptability are specified by the purchaser.

3.1.3 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248.

3.2 Melting Practice

Steel shall be produced by multiple melting using vacuum induction melting (VIM) in the initial melt and consumable electrode vacuum remelting (VAR) practice in the remelt cycle.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars, forgings, mechanical tubing, and flash-welded rings shall be annealed and descaled. Bars shall not be cut from plate (see 4.4.2).

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

3.3.2 Stock for forging or flash-welded rings shall be as ordered by the forging or flash-welded ring manufacturer.

3.4 Annealing

Bars, forgings, mechanical tubing, and flash-welded rings shall be annealed in accordance with AMS2761 by heating to a temperature within the range 1500 to 1700 °F (816 to 927 °C), holding at the selected temperature within ±25 °F (±14 °C) for a minimum of 1 hour, and cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool or faster.

3.5 Properties

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

3.5.1 Macrostructure

Visual examination of transverse full cross sections from bars, billets, tube rounds (solid, not hollow), and stock for forging or flash-welded rings, 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

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 bored/hollow forgings (including ring forgings) and mechanical tubing that are produced directly from ingots or blooms unless otherwise specified by the purchaser, in which case the purchaser shall specify standards to be used (see 8.7).

3.5.1.2 If mechanical tubing is produced directly from ingots or large blooms, transverse sections may be taken from the tubing. Macroetch standards for such tubes shall be as agreed upon by the purchaser and producer (see 8.7).

3.5.2 Micro-Inclusion Rating of Each Heat

No specimen shall exceed the limits shown in Table 3, determined in accordance with ASTM E45, Method A.

Table 3 - Micro-inclusion rating

Type	A	B	C	D	E
Thin	1.5	1.5	1.5	2.0	3.0
Heavy	1.0	1.0	1.0	1.5	1.5

3.5.2.1 Type E is titanium nitride and shall be rated in the same manner as Type B.

3.5.3 Hardness of Bars, Forgings, Mechanical Tubing, and Flash-Welded Rings as Annealed

Bars, forgings, tubing, and flash-welded rings shall have hardness not higher than 38 HRC, or equivalent (see 8.2).

3.5.4 Average Grain Size of Bars, Forgings, Mechanical Tubing, and Flash-Welded Rings

Product 5.000 inches (127.00 mm) and under in nominal section thickness shall be ASTM No. 6 or finer, determined in accordance with ASTM E112.

3.5.5 Response to Maraging Heat Treatment

Specimens from bars, forgings, tubing, and flash-welded rings shall have the following properties after being maraged by heating to 950 °F ± 10 °F (510 °C ± 6 °C), holding at heat for 3 to 6 hours, and cooling to room temperature:

3.5.5.1 Tensile Properties – Response to Maraging Heat Treatment

Tensile properties shall be as shown in Table 4.

Table 4A - Minimum longitudinal tensile properties, inch/pound units[(1)] - response to maraging heat treatment

Nominal Section Thickness Inches	Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 4D or 2 inches %
Up to 5.000, incl	Longitudinal	340	330	2.8

(1) The yield strength and elongation values are taken from MIL-S-46850. The tensile values are from industry practice. These properties were not independently substantiated using SAE/AMS statistical guidelines.

Table 4B - Minimum longitudinal tensile properties, SI units[(1)] - response to maraging heat treatment

Nominal Section Thickness Millimeters	Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D or 50 mm %
Up to 127.00, incl	Longitudinal	2344	2275	2.8

(1) The yield strength and elongation values are taken from MIL-S-46850. The tensile values are from industry practice. These properties were not independently substantiated using SAE/AMS statistical guidelines.

3.5.5.1.1 Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 in/in and 0.5 in/in (0.05 mm/mm and 0.5 mm/mm) of the length of the reduced section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 in/in/min and 0.5 in/in/min (0.05 mm/mm/min and 0.5 mm/mm/min).

3.5.5.1.2 Mechanical property requirements for product outside the size range covered by Table 4 shall be agreed upon between the purchaser and producer and reported per 4.4.4.

3.5.5.2 Hardness – Response to Maraging Heat Treatment

Hardness shall be not lower than 56 HRC, or equivalent (see 8.2), but the product shall not be rejected on the basis of hardness if the tensile property requirements are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.

3.5.6 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4 and 3.5.5, specimens taken from the heat-treated coupon shall conform to the requirements of 3.5.5.1 and 3.5.5.2. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.5 conform to the requirements of 3.5.5.1 and 3.5.5.2, 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 qualification of a smaller size.

3.5.7 Stock for Flash-Welded Rings

Specimens taken from the stock after heat treatment as in 3.4 and 3.5.5 shall conform to the requirements of 3.5.5.1 and 3.5.5.2.

3.6 Quality

The product, as received by the 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.

3.6.2 Bars and mechanical tubing shall be free from seams, laps, tears, and cracks after removal of the standard stock removal allowance in accordance with AS1182.

3.6.3 Flash-welded rings ordered ground, turned, or polished shall be free from seams, laps, tears, and cracks open to the ground, turned, or polished surfaces.

3.6.4 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.

3.7 Tolerances

3.7.1 Bar tolerances shall be in accordance with AMS2251.

3.7.2 Mechanical tubing tolerances shall be in accordance with AMS2253.

3.8 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.4.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for the producer's tests and shall be responsible for the performance of all required tests. The 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 (see 3.1), macrostructure (see 3.5.1), micro-inclusion rating (see 3.5.2), annealed hardness (see 3.5.3), average grain size (see 3.5.4), tensile properties (see 3.5.5.1), maraged hardness (see 3.5.5.2), and tolerances (see 3.7) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Frequency-severity cleanliness rating (see 3.6.1), and grain flow of die forgings (see 3.6.4) are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by the purchaser.

4.3 Sampling and Testing

4.3.1 Sampling and testing of bars, mechanical tubing, flash-welded rings, and stock for forging or flash-welded rings in accordance with AMS2370.

4.3.2 Sampling and testing of forgings shall be in accordance with AMS2372.