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| AEROSPACE MATERIAL SPECIFICATION | AMS6511™ | REV. C |
| | Issued | 2008-02 |
| | Revised | 2023-03 |
| Superseding AMS6511B | | |
| Steel, Maraging, Bars, Forgings, Mechanical Tubing, Rings, and Stock for Forging and Rings 18Ni - 8.5Co - 3.2Mo - 0.20Ti - 0.10Al Double Vacuum Melted, Annealed (Composition similar to UNS K92710) | | |

RATIONALE

AMS6511C is the result of a Five-Year Review and update of the specification. The revision updates the title to match the scope, adds a precaution based on susceptibility to stress corrosion cracking (1.2.1), adds reporting information (3.1.2), clarifies macrostructure requirements (3.5.1, 8.8), adds pyrometry requirements (3.5.5), updates testing to clarify transverse requirements (3.5.5.1), prohibits unauthorized exceptions (3.5.8, 8.6), and notes finish condition and machining tolerances (8.5).

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality steel in the form of bars, forgings, mechanical tubing, flash welded rings up through 6.000 inches (152.40 mm), and stock for forging or flash welded rings.

1.2 Application

These products have been used typically for parts requiring through-hardening, without liquid quenching, to yield strength of 200 ksi (1379 MPa) and where such parts may require welding during fabrication, 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. ARP 1110 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.

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For more information on this standard, visit
<https://www.sae.org/standards/content/AMS6511C/>

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 |
| 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 |
| 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 |
| ARP1110 | Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion-Resistant Steels and Alloys |
| 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 | 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

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

Table 1 - Composition

| Element | Min | Max |
|------------|-------|-------|
| Carbon | -- | 0.03 |
| Manganese | -- | 0.10 |
| Silicon | -- | 0.10 |
| Phosphorus | -- | 0.010 |
| Sulfur | -- | 0.010 |
| Nickel | 17.00 | 19.00 |
| Cobalt | 8.00 | 9.00 |
| Molybdenum | 3.00 | 3.50 |
| Titanium | 0.15 | 0.25 |
| 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; 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 Producer may test for any element not listed in Table 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 process in the initial melt and consumable electrode vacuum practice in the final melt (VIM VAR).

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars, Forgings, Mechanical Tubing, and Flash Welded Rings

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 purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS7496.

3.3.2 Stock for Forging or Flash Welded Rings

As ordered by the forging or flash welded ring manufacturer.

3.4 Annealing

Bars, forgings, mechanical tubing, and flash welded rings shall be annealed 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 1 hour minimum, and cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool or faster. Pyrometry shall be in accordance with AMS2750.

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 large blooms unless otherwise agreed upon by purchaser and producer (see 8.8).

3.5.1.2 If mechanical tubing is produced directly from ingots or large blooms, transverse sections may be taken from the tubing. Macrostructure standards shall be as agreed upon by purchaser and producer (see 8.8).

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 D.

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 32 HRC, or equivalent (see 8.2).

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

Product 6.000 inches (152.40 mm) and under in nominal section thickness shall be ASTM No. 5 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 900 °F ± 10 °F (510 °C ± 6 °C), holding at heat for 3 to 6 hours, and cooling to room temperature. Pyrometry shall be in accordance with AMS2750.

3.5.5.1 Tensile Properties

Shall be as shown in Table 4.

3.5.5.1.1 Testing in the longitudinal direction need not be performed on product tested in the transverse direction.

3.5.5.1.2 Transverse testing shall be determined on specimens selected and prepared in accordance with AMS2310. Transverse tensile properties apply only to product from which tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken.

Table 4A - Minimum tensile properties, inch/pound units⁽¹⁾

| Nominal Section Thickness Inches | Specimen Orientation | Tensile Strength ksi | Yield Strength at 0.2% Offset ksi | Elongation in 4D or 2 Inches % | Reduction of Area % |
|-------------------------------------|----------------------|-------------------------|--------------------------------------|--------------------------------------|------------------------|
| Up to 6.000, incl | Longitudinal | 205 | 200 | 8.0 | 50 |
| | Transverse | 205 | 200 | 8.0 | 40 |

⁽¹⁾ Properties have not been substantiated using SAE/AMS statistical guidelines (see 8.3).

Table 4B - Minimum tensile properties, SI units⁽¹⁾

| Nominal Section Thickness Millimeters | Specimen Orientation | Tensile Strength MPa | Yield Strength at 0.2% Offset MPa | Elongation in 4D or 50 Millimeters % | Reduction of Area % |
|--|----------------------|-------------------------|--------------------------------------|--|------------------------|
| Up to 152.40, incl | Longitudinal | 1413 | 1379 | 8.0 | 50 |
| | Transverse | 1413 | 1379 | 8.0 | 40 |

⁽¹⁾ Properties have not been substantiated using SAE/AMS statistical guidelines (see 8.3).

3.5.5.1.3 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).

3.5.5.2 Hardness

Shall be not lower than 42 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.

3.5.7 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.

3.5.8 Mechanical property requirements for product outside the size range covered by 1.1 shall be agreed upon between purchaser and producer and reported per 4.4.4.

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.

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 Bars

In accordance with AMS2251.

3.7.2 Mechanical Tubing

In accordance with AMS2253.

3.8 Any exceptions shall be authorized by 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 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), macrostructure (3.5.1), micro-inclusion rating (3.5.2), annealed hardness (3.5.3), average grain size (3.5.4), tensile properties (3.5.5.1), maraged hardness (3.5.5.2), and tolerances (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 (3.6.1) and grain flow of die forgings (3.6.4) 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, Flash Welded Rings, and Stock for Forging or Flash Welded Rings

In accordance with AMS2370.

4.3.2 Forgings

In accordance with AMS2372.

4.4 Reports

4.4.1 The producer of bars, forgings, tubing, and flash welded rings shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), results of tests for composition, macrostructure, micro-inclusion rating, and tensile properties and hardness after marage heat treatment of each heat, for average grain size 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, AMS6511C, product form, 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 If the ship size/shape is cut from a larger cross section, report the nominal metallurgically worked size (see 3.3.1).

4.4.3 The producer of stock for forging and flash welded rings shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), results of tests for composition, macrostructure, micro-inclusion rating, and tensile properties and hardness after marage heat treatment of each heat and the results of any additional property requirements imposed by 8.8. This report shall include the purchase order number, heat number, AMS6511C, size, and quantity.

4.4.4 When material produced to this specification is beyond the sizes allowed in the scope or tables, or other exceptions authorized by purchaser are taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS6511C(EXC) because of the following exceptions:" and the specific exceptions shall be listed (see 5.2.1).

4.5 Resampling and Retesting

4.5.1 Bars, Mechanical Tubing, Flash Welded Rings, and Stock for Forging or Flash Welded Rings

In accordance with AMS2370.

4.5.2 Forgings

In accordance with AMS2372.

5. PREPARATION FOR DELIVERY

5.1 Sizes

Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing will be acceptable in mill lengths of 6 to 20 feet (1.8 to 6.1 m), but not more than 10% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).