



<b>AEROSPACE MATERIAL SPECIFICATION</b>	<b>AMS6519™</b>	<b>REV. F</b>
	Issued 1986-01 Reaffirmed 2006-02 Revised 2024-08	
Superseding AMS6519E		
Steel, Maraging, Bars, Forgings, Mechanical Tubing, Flash-Welded Rings, and Stock for Forging and Flash-Welded Rings, 19Ni - 3.0Mo - 1.4Ti - 0.10Al (Alloy T250), Premium Aircraft Quality, Double Vacuum Melted, Annealed (Composition similar to UNS K92150)		

### RATIONALE

AMS6519F is the result of a Five-Year Review and update of the specification. The revision updates the Title to match the Scope and adds the common name, adds a note on stress corrosion (see 1.2.1), updates composition to require testing for calcium (see Table 1), adds composition reporting information (see 3.1.1), clarifies macrostructure (see 3.5.1 and 8.8), adds pyrometry (see 3.5.3.2), updates exceptions requirements (see 3.5.3.2.1.4, 4.4.4, and 8.7), adds forging stock property option (see 4.4.3), and provides guidance on stock removal (see 8.5).

## 1. SCOPE

### 1.1 Form

This specification covers a premium aircraft-quality, maraging steel in the form of bars, forgings, mechanical tubing, flash-welded rings up to 10.0 inches (254 mm) in diameter or least distance between parallel sides (thickness), and stock of any size for forging or flash-welded rings (see 8.6).

### 1.2 Application

These products have been used typically for parts, such as pressure vessels, requiring through hardening, without quenching, to a minimum yield strength of 240 ksi (1655 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. 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.

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## 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](http://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
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
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](http://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
ASTM E399	Linear-Elastic Plane-Strain Fracture Toughness $K_{Ic}$ of Metallic Materials

## 2.3 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	20.00
Molybdenum	2.75	3.25
Titanium	1.30	1.45
Aluminum	0.05	0.15
Chromium	--	0.50
Cobalt	--	0.50
Copper	--	0.50
Calcium <sup>(1)</sup>	--	0.05

<sup>(1)</sup> Standard Stock Removal Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel, Bars and Mechanical Tubing

3.1.1 The producer may test for any element not listed in Table 1 and include this analysis in the report of 4.5. 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.

#### 3.1.2 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 process (VIM) in the initial melt and vacuum consumable electrode remelt practice (VAR) in the final melt.

#### 3.3 Condition

##### 3.3.1 Bars

Bar shall be annealed and descaled. Bar shall not be cut from plate (see 4.4.2).

##### 3.3.2 Forgings, Mechanical Tubing, and Flash-Welded Rings

Forgings, mechanical tubing, and flash-welded rings shall be annealed and descaled.

3.3.2.1 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.

##### 3.3.3 Stock for Forgings or Flash-Welded Rings

Stock shall be 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 a temperature within the range 1500 to 1700 °F (816 to 927 °C), holding at the selected temperature within  $\pm 25$  °F ( $\pm 14$  °C) for 1 to 2 hours, 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.

### 3.5 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 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 bored/hollow forgings (including ring forgings) and mechanical tubing that are produced directly from ingots or blooms unless otherwise agreed upon by the purchaser and producer (see 8.8).

3.5.1.1.1 If mechanical tubing is produced directly from ingots or large blooms, transverse sections may be taken from the tubing. Macrostructure standards for such tubes shall be as agreed upon by the 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 nitrides and shall be rated in the same manner as Type B.

### 3.5.3 Bars, Wire, Forgings, Tubing, and Flash-Welded Rings

#### 3.5.3.1 Annealed Condition

##### 3.5.3.1.1 Hardness

Bars over 0.500 inch (12.70 mm) in nominal diameter or least distance between parallel sides, forgings, tubing, and flash-welded rings shall have hardness not higher than 321 HBW, or equivalent (see 8.2).

##### 3.5.3.1.2 Tensile Strength

Bars 0.500 inch (12.70 mm) and under in nominal diameter or least distance between parallel sides shall have tensile strength not higher than 160 ksi (1105 MPa) or equivalent hardness (see 8.3).

## 3.5.3.1.3 Average Grain Size

The average grain size shall be as follows, determined in accordance with ASTM E112:

3.5.3.1.3.1 Product under 2.50 inches (62.5 mm) in nominal section thickness shall be ASTM No. 6 or finer.

3.5.3.1.3.2 Product 2.50 to 10.00 inches (62.5 to 250.0 mm), inclusive, in nominal section thickness shall be ASTM No. 4 or finer.

## 3.5.3.2 Response to Maraging Heat Treatment

Samples from product shall have the properties shown in Table 4 after being maraged by heating to 900 °F ± 10 °F (482 °C ± 6 °C), holding at heat for 4 to 6 hours, and cooling to room temperature. Pyrometry shall be in accordance with AMS2750.

## 3.5.3.2.1 Tensile Properties

Response to heat treatment tensile properties shall be as shown in Table 4 and 3.5.3.2.1.1.

3.5.3.2.1.1 Longitudinal requirements apply to specimens taken with the axis of specimens approximately parallel to the grain flow and to specimens taken in the radial direction and in the tangential direction at the rim of disc forgings. All other specimens shall be considered to be in the transverse direction.

3.5.3.2.1.2 Transverse requirements apply only to product from which tensile specimens not less than 2.50 inches (62.5 mm) in length can be taken.

3.5.3.2.1.3 Tensile properties in the longitudinal direction need not be determined on product tested in the transverse direction.

**Table 4A - Minimum tensile properties - response to heat treatment, inch/pound units**

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 4.00, excl	Longitudinal	255	250	6	45
	Transverse	255	250	4	35
4.00 to 10.00, incl	Longitudinal	245	240	5	30
	Transverse	245	240	3	20

**Table 4B - Minimum tensile properties - response to heat treatment, SI units**

Nominal Section Thickness Millimeters	Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D or 50 mm %	Reduction of Area %
Up to 101.6, excl	Longitudinal	1760	1725	6	45
	Transverse	1760	1725	4	35
101.60 to 254.0, incl	Longitudinal	1690	1655	5	30
	Transverse	1690	1655	3	20

3.5.3.2.1.4 Mechanical property requirements for product outside of the range covered by 1.1 shall be agreed upon between the purchaser and producer and reported in 4.4.

3.5.3.2.1.5 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  $\pm 0.002$  in/in/min ( $\pm 0.002$  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 and 0.5 in/in (0.05 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 and 0.5 in/in/min (0.05 and 0.5 mm/mm/min).

#### 3.5.3.2.2 Hardness

Hardness shall be not lower than 48 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.

#### 3.5.3.2.3 Fracture Toughness

When specified, the product shall be subjected to fracture toughness testing. Method of test, location and orientation of specimens, and standards for acceptance shall be as agreed upon by the purchaser and producer. ASTM E399 is a suggested method of test.

#### 3.5.4 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4 and 3.5.3.2, specimens taken from the heat-treated coupon shall conform to the requirements of 3.5.3.2.1 and 3.5.3.2.2, and, when specified, 3.5.3.2.3. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.3.2 conform to the requirements of 3.5.3.2.1 and 3.5.3.2.2, and, when specified, 3.5.3.2.3, the tests shall be accepted as equivalent to tests of a forged coupon.

#### 3.5.5 Stock for Flash-Welded Rings

A sample of stock heat treated as in 3.4 and 3.5.3.2 shall conform to the requirements of 3.5.3.2.1, 3.5.3.2.2, and, when specified, 3.5.3.2.3.

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

### 3.7 Tolerances

#### 3.7.1 Bars

Bar tolerances shall be in accordance with AMS2251.

#### 3.7.2 Mechanical Tubing

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

Tests for the following requirements are acceptance tests and shall be performed on each heat or lot as applicable:

- Composition (see 3.1), macrostructure (see 3.5.1), micro-inclusion rating (see 3.5.2), and frequency-severity cleanliness rating (see 3.6.1) of each heat.
- Hardness (see 3.5.3.1.1) or tensile properties (see 3.5.3.1.2), as applicable, of each lot of bars, forgings, tubing, and flash-welded rings as annealed.
- Average grain size (see 3.5.3.1.3) of each lot of bars, forgings, tubing, and flash-welded rings as annealed.
- Tensile properties (see 3.5.3.2.1) and hardness (see 3.5.3.2.2) of each lot of bars, forgings, tubing, and flash-welded rings after maraging heat treatment.
- Tolerances of bars (see 3.7.1) and mechanical tubing (see 3.7.2).
- When specified, fracture toughness (see 3.5.3.2.3) of the product.

#### 4.2.2 Periodic Tests

Tests for grain flow of die forgings (see 3.6.3) and ability of forging stock (see 3.5.4) and of stock for flash-welded rings (see 3.5.5) to develop required properties 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 Bars, mechanical tubing, flash-welded rings, and stock for forging or flash-welded rings shall be sampled and tested in accordance with AMS2370.

4.3.2 Forgings shall be sampled and tested in accordance with AMS2372.

### 4.4 Reports

4.4.1 The producer of forgings, tubing and flash-welded rings shall furnish with each shipment a report showing the producer's 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 frequency-severity rating of each heat; results of tests for annealed hardness and average grain size, for tensile properties, hardness, and, when specified, fracture toughness after maraging 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, AMS6519F, 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 be included.

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