

Steel, Maraging, Bars, Forgings, Tubing, and Rings  
18Ni - 8.5Co - 3.2Mo - 0.20Ti - 0.10Al  
Double Vacuum Melted, Annealed  
(Composition similar to UNS K92710)

## RATIONALE

AMS 6511 is a new specification to cover UNS K92710.

### 1. SCOPE

#### 1.1 Form

This specification covers a premium aircraft-quality 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 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.

### 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 supplied 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](http://www.sae.org).

AMS 2248	Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly Alloyed Steels, and Iron Alloys
AMS 2251	Tolerances, Low-Alloy Steel Bars
AMS 2253	Tolerances, Carbon and Alloy Steel Tubing
AMS 2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure
AMS 2370	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Wrought Products and Forging Stock
AMS 2372	Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Forgings
AMS 2750	Pyrometry

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AMS 2806	Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS 2808	Identification, Forgings
AMS 7496	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](http://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

## 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	--	0.03
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 Check Analysis

Composition variations shall meet the applicable requirements of AMS 2248.

### 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.

### 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.

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 AMS 7496.

#### 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  $\pm 25$  °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 or faster. Pyrometry shall be in accordance with AMS 2750.

### 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 Heat of Steel

##### 3.5.1.1 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, for product 36 square inches (232 cm<sup>2</sup>) and under in nominal cross-sectional area, shall be no worse than the macrographs of ASTM A 604 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

##### 3.5.1.2 Micro-Inclusion Rating

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

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

### 3.5.2 Bars, Forgings, Mechanical Tubing, and Flash Welded Rings

#### 3.5.2.1 As Annealed

##### 3.5.2.1.1 Hardness

Bars, forgings, tubing, and flash welded rings shall have hardness not higher than 32 HRC, or equivalent (See 8.2).

##### 3.5.2.1.2 Average Grain Size

Shall be as follows, determined in accordance with ASTM E 112.

##### 3.5.2.1.2.1 Product 6.0 Inches (152.4 mm) and under in Nominal Section Thickness

ASTM No. 5 or finer.

#### 3.5.2.2 Response to Maraging Heat Treatment

Specimens shall have the following properties after being maraged by heating to  $900\text{ }^{\circ}\text{F} \pm 10$  ( $510\text{ }^{\circ}\text{C} \pm 6$ ), holding at heat for 3 to 6 hours, and cooling to room temperature: This requirement for Response to Heat Treatment evaluates the capability of the material, but does not describe the "as supplied" heat treat condition of the material - See 3.3 Condition.

##### 3.5.2.2.1 Tensile Properties

Shall be as shown in Table 4.

TABLE 4A - MINIMUM TENSILE PROPERTIES, INCH/POUND UNITS<sup>(1)</sup>

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

TABLE 4B - MINIMUM TENSILE PROPERTIES, SI UNITS<sup>(1)</sup>

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

<sup>(1)</sup> (See 8.3)

##### 3.5.2.2.2 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.

### 3.5.3 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4 and 3.5.2.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.2.2.1 and 3.5.2.2.2. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.2.2 conform to the requirements of 3.5.2.2.1 and 3.5.2.2.2, the tests shall be accepted as equivalent to tests of a forged coupon.

### 3.5.4 Stock for Flash Welded Rings

Specimens taken from the stock after heat treatment as in 3.4 and 3.5.2.2 shall conform to the requirements of 3.5.2.2.1 and 3.5.2.2.2.

## 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 AMS 2300.

3.6.2 Bars and mechanical 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 ground, turned, or polished surface.

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 which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

## 3.7 Tolerances

Shall be as follows:

### 3.7.1 Bars

In accordance with AMS 2251.

### 3.7.2 Mechanical Tubing

In accordance with AMS 2253.

## 4. QUALITY ASSURANCE PROVISIONS

### 4.1 Responsibility for Inspection

The vendor of the product shall supply all samples for vendor'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 (3.5.1.1), micro-inclusion rating (3.5.1.2), hardness (3.5.2.1.1), average grain size (3.5.2.1.2), tensile properties (3.5.2.2.1), hardness (3.5.2.2.2), frequency-severity cleanliness rating (3.6.1), and tolerances (3.7) are acceptance tests and shall be performed on each heat or lot as applicable.

#### 4.2.2 Periodic Tests

Capability of forging stock (3.5.3) and stock for flash welded rings (3.5.4) to develop required properties and grain flow of die forgings (3.6.4) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.