SAE Aerospace
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# AEROSPACE MATERIAL SPECIFICATION

SAE AMS6516

Issued 2011-07

Steel, Bars and Forgings
1Cr – 10Ni – 7Co – 2Mo – 1.3W – 0.1V – (0.28 – 0.32C)
Vacuum Induction Melted, Vacuum Arc Remelted, Normalized and Annealed
Precipitation Hardenable

(Composition similar to UNS K91973)

RATIONALE

AMS6516 is a new specification for UNS K91973.

## 1. SCOPE

### 1.1 Form

This specification covers a premium aircraft-quality alloy steel in the form of bars, forgings, and forging stock.

### 1.2 Application

These products have been used typically for heat treated parts requiring a combination of high strength, high toughness, and weldability, 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.

### 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

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

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





**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**

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

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 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 | 0.28 | 0.32 |
| Manganese | -- | 0.1 |
| Silicon | -- | 0.1 |
| Phosphorus | -- | 0.008 |
| Sulfur | -- | 0.006 |
| Chromium | 0.7 | 1.3 |
| Nickel | 9.5 | 10.5 |
| Cobalt | 6.6 | 7.4 |
| Molybdenum | 1.8 | 2.2 |
| Tungsten | 1.1 | 1.5 |
| Titanium | -- | 0.045 |
| Aluminum | -- | 0.01 |
| Vanadium | 0.04 | 0.16 |
| Oxygen | -- | 0.0020 (20 ppm) |
| Nitrogen | -- | 0.0015 (15 ppm) |

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2259.

3.2 Melting Practice

Steel shall be multiple melted using vacuum induction melting followed by vacuum arc remelting.

3.3 Condition

The product shall be supplied in the following condition; hardness shall be determined in accordance with ASTM A 370:

3.3.1 Bars

Normalized and annealed, having hardness not higher than 429 HB or equivalent (See 8.2), and ground or turned. Bar shall not be cut from plate.

3.3.2 Forgings

Normalized and annealed, having hardness not higher than 429 HB or equivalent (See 8.2), and descaled.

3.3.3 Forging Stock

As ordered by the forging manufacturer.

3.4 Heat Treatment

Shall conform to the following:

3.4.1 Bars and Forgings

Shall be normalized by heating to 1965 °F ± 25 (1074 °C ± 14), holding at heat for 60 minutes +60, -0, and cooling in air to room temperature, and annealed by heating to between 1155 and 1255 °F (624 and 679 °C), holding at heat for 8 hours minimum, and air cooled. Pyrometry shall be in accordance with AMS2750.

3.4.2 Forging Stock

As ordered by the forging manufacturer.

3.5 Properties

The product shall conform to the following requirements.:

3.5.1 Macrostructure

Visual examination of transverse full cross-sections from bars, billets, and forging stock, 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 $cm^2$) and under in nominal cross-sectional area shall be no worse than the macrostructure limits 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 |

3.5.2 Micro-Inclusion Rating of each Heat

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

TABLE 3 - MICRO-INCLUSION RATING LIMITS

| Type | A | B | C | D |
|---|---|---|---|---|
| Thin | 1.5 | 1.5 | 1.5 | 1.5 |
| Thick | 1.0 | 1.0 | 1.0 | 1.0 |

3.5.3 Response to Heat Treatment

3.5.3.1 Bars and Forgings

Test specimens in the normalized and annealed condition as specified in 3.4.1, cut from product 189 square inches (1219 $cm^2$) and under in cross-sectional area, shall meet the properties specified in 3.5.3.1.1, 3.5.3.1.2, 3.5.3.1.3, and 3.5.3.1.4 after being solution treated by heating to 1940 °F ± 25 (1060 °C ± 14), holding at heat for 60 minutes + 30, -0, quenching in oil (or equivalent), cooling to -100 °F (-73 °C) or lower, holding at temperature for minimum 1 hour, and air warming to room temperature; and tempered by heating to 960 °F ± 12 (516 °C ± 7), holding at heat for 10 hours ± 2, and cooling in air (or equivalent).

3.5.3.1.1 Tensile Properties

In accordance with ASTM A 370.

3.5.3.1.1.1 Longitudinal

Shall be as shown in Table 4; testing in the longitudinal direction need not be performed on product tested in the transverse direction.

TABLE 4 - MINIMUM LONGITUDINAL TENSILE PROPERTIES

| Property | Value |
|---|---|
| Tensile Strength | 285 ksi (1965 MPa) |
| Yield Strength at 0.2% Offset | 240 ksi (1655 MPa) |
| Elongation in 4D | 10% |
| Reduction of Area | 55% |

3.5.3.1.1.2 Transverse

Shall be as shown in Table 5, determined on specimens selected and prepared in accordance with AMS2310. Transverse properties apply only to product from which tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken.

TABLE 5 - MINIMUM TRANSVERSE TENSILE PROPERTIES

| Property | Value |
|---|---|
| Tensile Strength | 285 ksi (1965 MPa) |
| Yield Strength at 0.2% Offset | 240 ksi (1655 MPa) |
| Elongation in 4D | 10% |
| Reduction of Area | 45% |

3.5.3.1.2 Hardness

Shall be not lower than 53 HRC or equivalent (See 8.2) in accordance with ASTM A 370.

3.5.3.1.3 Fracture Toughness

Shall be not lower than 100 ksi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$) $K_{IC}$, determined in accordance with ASTM E 399 on specimens in the longitudinal LS or LR orientation from product 3.00 inches (76.2 mm) and over in nominal section thickness. If product size precludes use of specimens that will provide valid $K_{IC}$ results, a $K_Q$ value not lower than 100 ksi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$) will be acceptable.

3.5.3.1.3.1 Invalid test results in accordance with ASTM E 399 shall be considered meaningful and the material shall be accepted to $K_{IC}$ requirements if the thickest possible specimen was used and the calculated $K_Q$ equals or exceeds the required $K_{IC}$ and invalidity is due to one or both of the following conditions:

a. B<2.5 (Kq/Oty)2

b. Pmax/Pq>1.10

3.5.3.1.4 Average Grain Size

Shall be ASTM No. 5 or finer for product 189 square inches (1219 $cm^2$) and under in cross-sectional area, determined in accordance with ASTM E 112.

3.5.3.2 Forging Stock

A sample of stock shall be forged to a test coupon and heat treated as in 3.5.3.1, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.3.1.1, 3.5.3.1.2, 3.5.3.1.3, and 3.5.3.1.4. Alternatively, specimens taken from stock after heat treatment as in 3.5.3.1 that conform to the requirements of 3.5.3.1.1, 3.5.3.1.2, 3.5.3.1.3, and 3.5.3.1.4, shall be accepted as equivalent to tests of a forged coupon.

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 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 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

Bars shall conform to all applicable requirements of AMS2251.

## 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

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

4.2.1.1 Composition (3.1), macrostructure (3.5.1), and micro-inclusion rating (3.5.2) of each heat.

4.2.1.2 Hardness maximum (3.3.1) of as supplied normalized and annealed product of each lot of bars and forgings.

4.2.1.3 Tensile properties ( 3.5.3.1.1), hardness (3.5.3.1.2), fracture toughness (3.5.3.1.3), and average grain size (3.5.3.1.4) of each lot of bars and forgings after heat treatment as specified in 3.5.3.1.

4.2.1.4 Tolerances (3.7) of bars.

#### 4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:

4.2.2.1 Ability of forging stock to develop required properties (3.5.3.2).

4.2.2.2 Frequency-severity cleanliness rating (3.6.1).

4.2.2.3 Grain flow of die forgings (3.6.3).

### 4.3 Sampling and Testing

#### 4.3.1 For Acceptance Tests

4.3.1.1 Bars and Forging Stock

In accordance with AMS2370.

4.3.1.2 Forgings

In accordance with AMS2372.

### 4.4 Reports

4.4.1 The vendor of bars and forgings shall furnish with each shipment a report showing the results of tests for chemical composition, macrostructure, and micro-inclusion rating of each heat, and for tensile properties, hardness, fracture toughness and 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, AMS6516, 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 also be included.