AEROSPACE MATERIAL SPECIFICATION

AMS6532™	REV. J

Issued 1992-07
Revised 2022-01

Superseding AMS6532H

Steel, Bars and Forgings, and Forging Stock 3.1Cr - 11.5Ni - 13.5Co - 1.2Mo (0.21 - 0.25C) Vacuum Melted, Normalized and Overaged Precipitation Hardenable

(Composition similar to UNS K92580)

RATIONALE

AMS6532J is the result of a Five-Year Review and update of the specification. The revision updates the title to match the scope, updates the form to address size limits within the specification (1.1), updates the prohibition on substitutions (3.5.4.1.5, 8.6), incorporates AS6279 as a requirement (3.8), incorporates tables for clarity (Table 4 and 7), and adds additional notes on AS1182 (8.5).

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality alloy steel in the form of bars, forgings 100 square inches (645 cm^2) and under in cross-sectional area and forging stock of any size.

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 +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

AMS2300 Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure

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/AMS6532J

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

ARP1917 Clarification of Terms Used in Aerospace Metals Specifications

AS1182 Standard Stock Removal Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

AS6279 Standard Practice for Production, Distribution, and Procurement of Metal Stock

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

ASTM E399 Plane-Strain Fracture Toughness of Metallic Materials

ASTM E1077 Estimating the Depth of Decarburization of Steel Specimens

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	0.21	0.25
Manganese	--	0.10
Silicon	--	0.10
Phosphorus	--	0.008
Sulfur	--	0.005
Phosphorus + Sulfur	--	0.010
Chromium	2.90	3.30
Nickel	11.00	12.00
Cobalt	13.00	14.00
Molybdenum	1.10	1.30
Titanium	--	0.015
Aluminum	--	0.015
Oxygen	--	0.0020 (20 ppm)
Nitrogen	--	0.0015 (15 ppm)

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248.

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 A370:

3.3.1 Bars

Normalized and overaged, having hardness not higher than 372 HB, or equivalent (see 8.2), and ground or turned. Bar shall not be cut from plate (also see 4.4.2).

3.3.2 Forgings

Normalized and overaged, having hardness not higher than 372 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 1650 °F ± 25 °F (899 °C ± 14 °C), holding at heat for 60 minutes ± 15 minutes, and cooling in air to a temperature between 45 °F and 200 °F (7 °C and 93 °C), and overaged by heating to 1250 °F ± 25 °F (677 °C ± 14 °C), holding at heat for 16 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 A604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections shall be no worse than the macrostructure limits 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

3.5.2 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 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 Decarburization

3.5.3.1 Bars and forging stock ordered ground or turned shall be free from decarburization on the ground or turned surfaces when determined in accordance with 3.5.3.3.

3.5.3.2 Forgings shall be supplied with a maximum decarburization of 0.040 inch (1.00 mm) when determined in accordance with 3.5.3.3, unless otherwise specified.

3.5.3.3 Decarburization shall be measured by the microscopic method per ASTM E1077.

3.5.4 Response to Heat Treatment

3.5.4.1 Bars and Forgings

Test specimens in the normalized and overaged condition as specified in 3.4.1, cut from product 100 square inches (645 cm^2) and under in cross-sectional area, shall meet the properties specified in 3.5.4.1.1, 3.5.4.1.2, 3.5.4.1.3, and 3.5.4.1.4 when subjected to the heat treatment in Table 4. Response to heat treatment verification need be performed only on the 900 °F age (482 °C) unless the purchaser specifies the 875 °F age (468 °C).

Table 4 - Response to heat treatment processing

Processing Step [1]		Temperature	Time at Temperature
1	Austenitization	1625 °F ± 25 °F (885 °C ± 14 °C)	60 minutes +15 /-0 minutes
2	Quench	Within 1 hour to 400 °F (204 °C) and Within 2 hours to 150 °F (204 °C) Air cool or faster to room temperature	
3	Cold Stabilization	Start within 8 hours	
		-100 °F ± 15 °F (-73 °C ± 8 °C)	1 hour minimum
4	Warm in air to room temperature		
5	900 °F (482 °C) Age	900 °F[2] ± 10 °F (482 °C ± 6 °C)	5-8 hours
5A	875 °F (468 °C) Age (alternate when specified)	875 °F[3] ± 10 °F (468 °C ± 6 °C)	5-8 hours

[1] Note that all processing must be performed in the order noted.
[2] Forgings with variable section thickness may be aged at 890 °F ± 10 °F (477 °C ± 6 °C) to avoid overaging of thin sections.
[3] Forgings with variable section thickness may be aged at 865 °F ± 10 °F (463 °C ± 6 °C) to avoid overaging of thin sections.

3.5.4.1.1 Tensile Properties

In accordance with ASTM A370. 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 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).

3.5.4.1.1.1 Longitudinal

Shall be as shown in Table 5; testing in the longitudinal direction need not be performed on product tested in the transverse direction.

Table 5 - Minimum longitudinal tensile properties

Property	Value Aged at 900 °F	Value Aged at 875 °F
Tensile Strength	280 ksi (1931 MPa)	290 ksi (1999 MPa)
Yield Strength at 0.2% Offset	235 ksi (1620 MPa)	245 ksi (1689 MPa)
Elongation in 4D	10%	10%
Reduction of Area	55%	50%

3.5.4.1.1.2 Transverse

Shall be as shown in Table 6, determined on specimens selected and prepared in accordance with AMS2310. Transverse properties apply only to product that tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken.

Table 6 - Minimum transverse tensile properties

Property	Value Aged at 900 °F	Value Aged at 875 °F
Tensile Strength	280 ksi (1931 MPa)	290 ksi (1999 MPa)
Yield Strength at 0.2% Offset	235 ksi (1620 MPa)	245 ksi (1689 MPa)
Elongation in 4D	8%	8%
Reduction of Area	45%	35%

3.5.4.1.2 Hardness

Shall be not lower than 53 HRC or equivalent (see 8.2) after 900 °F age, or not lower than 54 HRC or equivalent (see 8.2) after 875 °F age, in accordance with ASTM A370.

3.5.4.1.3 Fracture Toughness

3.5.4.1.3.1 Fracture toughness shall meet the applicable criteria of Table 7. Fracture Toughness, KIC, determined in accordance with ASTM E399 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 KIC results, a KQ value not lower than listed KIC will be acceptable

Table 7 - Fracture toughness

Age Temperature[1]	Fracture Toughness, minimum
900 °F (482 °C)	100 ksi $\sqrt{\text{inch}}$ (110 MPa $\sqrt{\text{m}}$) K_{IC}
875 °F (468 °C)	80 ksi $\sqrt{\text{inch}}$ (88 Mpa $\sqrt{\text{m}}$) K_{IC}

[1] See Table 4, row 5 and 5a.

3.5.4.1.3.2 Invalid test results in accordance with ASTM E399 shall be considered meaningful and the material shall be accepted to KIC requirements if the thickest possible specimen was used and the calculated KQ equals or exceeds the required KIC and invalidity is due to one or both of the following conditions:

a. $W\text{-}a < 2.5 (K_Q/\sigma_{YS})^2$

b. $P_{max}/P_Q > 1.10$

3.5.4.1.4 Average Grain Size

Shall be ASTM No. 8 or finer for product 100 square inches (645 cm^2) and under in cross-sectional area, determined in accordance with ASTM E112.

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

3.5.4.2 Forging Stock

A sample of stock shall be forged to a test coupon acceptable to purchaser and heat treated as in 3.5.4.1. Specimens taken from the heat treated coupon shall conform to the requirements of 3.5.4.1.2, 3.5.4.1.3, 3.5.4.1.4, and 3.5.4.1.5. Alternately specimens taken from stock after heat treatment as in 3.5.4.1 that conform to the requirements of 3.5.4.1.2, 3.5.4.1.3, 3.5.4.1.4, and 3.5.4.1.5 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, except that a maximum average frequency (F) rating of 0.10 and a maximum average severity (S) rating of 0.20 shall apply.

3.6.2 Bars 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 forgings showing no evidence of reentrant grain flow.

3.7 Tolerances

Bars shall conform to all applicable requirements of AMS2251.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279. The requirement for compliance with AS6279 becomes effective (18 months from date of publication).

3.9 Exceptions

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 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) and decarburization analysis (3.5.3) of as supplied normalized and overaged product of each lot of bars and forgings

4.2.1.3 Tensile properties (3.5.4.1.2), hardness (3.5.4.1.3), fracture toughness (3.5.4.1.4), and average grain size (3.5.4.1.5) of each lot of bars and forgings after heat treatment using the 900 °F (482 °C) aging temperature or the 875 °F (468 °C) aging temperature, if specified by purchaser.

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 producer unless frequency of testing is specified by purchaser:

4.2.2.1 Tensile properties (3.5.4.1.2), hardness (3.5.4.1.3), and fracture toughness (3.5.4.1.4), and average grain size (3.5.4.1.5) of each lot of bars or forgings after heat treatment using the 875 °F aging temperature as specified in 3.5.4.1.

4.2.2.2 Ability of forging stock to develop required properties (3.5.4.2).

4.2.2.3 Frequency-severity cleanliness rating (3.6.1).

4.2.2.4 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.