ADOPTION NOTICE

SAE-AMS6478, "STEEL, BARS AND FORGINGS 3.1CR - 11.5NI - 13.5CO - 1.2MO(0.21 - 0.25C) VACUUM MELTED, ANNEALED HEAT TREATABLE TO 290 KSI (1999 MPA) TENSILE STRENGTH", was adopted on 31-MAY-94 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: ASC/ENOI, Building 560, 2530 Loop Road West, Wright-Patterson AFB, OH 45433-7101. Copies of this document may be purchased from the Society of Automotive Engineers 400 Commonwealth Drive Warrendale, Pennsylvania, United States, 15096-0001. http://www.sae.org/

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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 6478

Issued MAY 1994
Reaffirmed SEP 2000

Steel, Bars and Forgings
3.1Cr - 11.5Ni - 13.5Co - 1.2Mo (0.21 - 0.25C)
Vacuum Melted, Annealed
Heat Treatable to 290 ksi (1999 MPa) Tensile Strength

UNS K92580

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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 parts requiring a combination of high strength, high toughness, and weldability, but usage is not limited to such applications. Product after proper heat treatment should attain a minimum tensile strength of 290 ksi (1999 MPa) and yield strength of 245 ksi (1689 MPa).

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2251	Tolerances, Low-Alloy Steel Bars
MAM 2251	Tolerances, Metric, Low-Alloy Steel Bars
AMS 2259	Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
AMS 2300	Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
MAM 2300	Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
AMS 2310	Qualification Sampling and Testing of Steels, Transverse Tensile Properties
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 2806	Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat Resistant Steels and Alloys
AMS 2808	Identification, Forgings
AS1182	Standard Machining Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM A 370	Mechanical Testing of Steel Products
ASTM A 604	Macrotech Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E 45	Determining the Inclusion Content of Steel
ASTM E 112	Determining the 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

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-163	Steel Mill Products, Preparation for Shipment and Storage

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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	0.21	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)

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3.1.1 Check Analysis: Composition variations shall meet the requirements of AMS 2259.

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:

3.3.1 Bars and Forgings: Annealed to a hardness not higher than 372 HB, or equivalent (See 8.1), determined in accordance with ASTM A 370, and descaled.

3.3.2 Forging Stock: As ordered by the forging manufacturer.

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3.4 Heat Treatment:

Shall conform to the following:

3.4.1 Bars: Shall be annealed by heating to 1250 °F ± 25 (677 °C ± 14), holding at heat for not less than 16 hours, and cooling in air.

3.4.2 Forgings: Shall be normalized by heating to 1650 °F ± 25 (899 °C ± 14), holding at heat for 60 minutes ± 15, cooling in air to room temperature, and annealed by heating to 1250 °F ± 25 (677 °C ± 14), holding at heat for not less than eight hours, and forced-air cooling.

3.5 Properties:

The product shall conform to the following requirements; tensile and hardness testing shall be performed in accordance with ASTM A 370:

3.5.1 Macrostructure: Visual examination of transverse 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 macrograph standards of ASTM A 604 shown in Table 2.

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TABLE 2 - Macrostructure Standards

Class	Condition	Severity
1	Freckles	A
2	White Spots	A
3	Radial Segregation	B
4	Ring Pattern	B

3.5.2 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

	A Thin	A Heavy	B Thin	B Heavy	C Thin	C Heavy	D Thin	D Heavy
Worst Field Severity	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Worst Field Frequency, maximum	*	1	*	1	*	1	3	1
Total Rateable Fields Frequency, maximum	**	1	**	1	**	1	8	1

* Combined A+B+C, not more than 3 fields
** Combined A+B+C, not more than 8 fields

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3.5.2.1 A rateable field is defined as one which has a type A, B, C, or D inclusion rating of at least 1.0 thin or heavy in accordance with the Jernkontoret Chart, Plate III, ASTM E 45.

3.5.3 Response to Heat Treatment:

3.5.3.1 Bars and Forgings: Test specimens cut from product 100 square inches (645 cm^2) and under in cross-sectional area that have been annealed as in 3.4 shall have the following properties after heating to 1625 °F ± 25 (885 °C ± 14), holding at heat for 60 to 75 minutes, and cooling at a rate equivalent to an air cool to ambient temperature, cooling to -100 °F ± 15 (-73 °C ± 8), holding at temperature for 60 minutes ± 5, warming at a rate equivalent to an air warm to room temperature, and aged by heating to 875 °F ± 10 (469 °C ± 6) (See 8.2), holding at heat for five to eight hours, and cooling at a rate equivalent to an air cool. Specimens over 1.25 inches (31.8 mm) thickness shall be oil quenched from 1625 °F ± 25 (885 °C ± 14). Properties of product over 100 square inches (645 cm^2) in cross-sectional area shall be agreed upon by purchaser and vendor.

3.5.3.1.1 Tensile Properties:

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	290 ksi (1999 MPa)
Yield Strength at 0.2% Offset	245 ksi (1689 MPa)
Elongation in 4D	10%
Reduction of Area	50%

3.5.3.1.1.2 Transverse: Shall be as shown in Table 5, determined on specimens selected and prepared in accordance with AMS 2310. 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 - Minimim Transverse Tensile Properties

Property	Value
Tensile Strength	290 ksi (1999 MPa)
Yield Strength at 0.2% Offset	245 ksi (1689 MPa)
Elongation in 4D	8%
Reduction of Area	35%

3.5.3.1.2 Hardness: Shall be not lower than 54 HRC, or equivalent (See 8.1).

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3.5.3.1.3 Fracture Toughness: Shall be not lower than 80 ksi $\sqrt{inch}$ (88 MPa $\sqrt{m}$) 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 standard 1.00 inch (25.4 mm) thick specimens are not capable, due to section size, of yielding a K_{IC} value, the K_Q value will be acceptable.

3.5.3.1.4 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 E 112.

3.5.3.2 Forging Stock: Stock, when heat treated as in 3.4 and 3.5.3.1, shall conform to the requirements of 3.5.3.1.1.1 and/or 3.5.3.1.1.2, 3.5.3.1.2, 3.5.3.1.3, and 3.5.3.1.4. Test specimens may be taken from the stock or from a sample of stock forged to a test 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 AMS 2300 or MAM 2300, 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 ordered hot rolled or cold drawn, or ground, turned, or polished shall, after removal of the standard machining allowance in accordance with AS1182, be free from seams laps, tears, and cracks open to the ground, turned, or polished surfaces.

3.6.3 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 re-entrant grain flow.

3.7 Tolerances:

Bars shall conform to all applicable requirements of AMS 2251 or MAM 2251.

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 performing all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

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:

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4.2.1.1 Composition (3.1), macrostructure (3.5.1), micro-inclusion rating (3.5.2), and frequency-severity cleanliness rating (3.6.1) of each heat.

4.2.1.2 Tensile properties (3.5.3.1.1.1 and/or 3.5.3.1.1.2), hardness (3.5.3.1.2), and grain size (3.5.3.1.4) of each lot of bars and forgings after heat treatment.

4.2.1.3 Tolerances (3.7) of bars.

4.2.2 Periodic Tests: Tests for 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 Fracture toughness (3.5.3.1.3) of bars and forgings after heat treatment.

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

4.2.2.3 Grain flow of die forgings (3.6.3).

4.3 Sampling and Testing:

Shall be as follows:

4.3.1 Bars and Forging Stock: In accordance with AMS 2370.

4.3.2 Forgings: In accordance with AMS 2372.

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, micro-inclusion rating, and frequency-severity cleanliness rating of each heat and for tensile properties, hardness, and grain size of each lot and, when performed, the results of tests to determine conformance to the periodic test requirements. This report shall include the purchase order number, heat and lot number, AMS 6478, size and quantity. When forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.4.2 The vendor of forging stock shall furnish with each shipment a report showing the results of tests for chemical composition and frequency-severity cleanliness rating of each heat. This report shall include the purchase order number, heat number, AMS 6478, size and quantity.

4.5 Resampling and Retesting:

Shall be as follows:

4.5.1 Bars and Forging Stock: In accordance with AMS 2370.

4.5.2 Forgings: In accordance with AMS 2372.

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