

Steel, Bars and Forgings
2.0Cr - 10Ni - 14Co - 1.0Mo (0.15 - 0.19C)
Vacuum Melted, Normalized and Overaged
(Composition similar to UNS K92571)

RATIONALE

AMS6527E results from a Five Year review and update of this specification.

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, 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
AMS2248	Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys
AMS2300	Steel Cleanliness, Premium Aircraft-Quality, Magnetic Particle Inspection Procedure
AMS2310	Qualification Sampling and Testing of Steels, Transverse Tensile Properties

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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
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 604	Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E 8 / E 8M	Tension Testing of Metallic Materials
ASTM E 18	Rockwell Hardness of Metallic Materials
ASTM E 23	Notched Bar Impact Testing of Metallic Materials
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 384	Knoop and Vickers Hardness of Materials
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	0.15	0.19
Manganese	--	0.10
Silicon	--	0.10
Phosphorus	--	0.008
Sulfur	--	0.005
Phosphorus + Sulfur	--	0.010
Chromium	1.80	2.20
Nickel	9.50	10.50
Cobalt	13.50	14.50
Molybdenum	0.90	1.10
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 consumable electrode practice.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars and Forgings

Normalized and overaged with hardness not higher than 36 HRC, or equivalent (See 8.2), determined in accordance with ASTM E 18. Bar shall not be cut from plate.

3.3.2 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 $1650^{\circ}\text{F} \pm 25$ ($899^{\circ}\text{C} \pm 14$), holding at heat for 60 minutes ± 5 , and cooling to room temperature at a rate equivalent to a still air cool or faster, and overaged by heating to $1250^{\circ}\text{F} \pm 25$ ($677^{\circ}\text{C} \pm 14$), holding at heat for not less than six hours, and fan-air cooling. Pyrometry shall be in accordance with AMS2750.

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 shall be no worse than the macrographs 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

No specimen shall exceed the limits shown in Table 3, determined in accordance with ASTM E 45, Method D, except that the length of any inclusion shall be not greater than 0.015 inch (0.38 mm).

TABLE 3 - MICRO-INCLUSION RATING LIMITS

Field	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	^a	1	^a	1	^a	1	3	1
Total Rateable Fields Frequency, maximum	^b	1	^b	1	^b	1	8	1

^a Combined A+B+C, not more than 3 fields
^b Combined A+B+C, not more than 8 fields

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 I-r, ASTM E 45.

3.5.3 Decarburization

3.5.3.1 Bars ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces.

3.5.3.2 Allowable decarburization of bars and billets ordered for redrawing or forging or to specified microstructural requirements shall be as agreed upon by purchaser and vendor.

3.5.3.3 Decarburization of bars to which 3.5.3.1 or 3.5.3.2 is not applicable shall be no greater than shown in Table 4.

TABLE 4A - MAXIMUM DECARBURIZATION, BARS, INCH/POUND UNITS

Nominal Diameter or Distance Between Parallel Sides Inches	Total Depth of Decarburization Inch
Up to 0.375, incl	0.015
Over 0.375 to 0.500, incl	0.017
Over 0.500 to 0.625, incl	0.019
Over 0.625 to 1.000, incl	0.022
Over 1.000 to 1.500, incl	0.025
Over 1.500 to 2.000, incl	0.030
Over 2.000 to 2.500, incl	0.035
Over 2.500 to 4.000, incl	0.040

TABLE 4B - MAXIMUM DECARBURIZATION, BARS, SI UNITS

Nominal Diameter or Distance Between Parallel Sides Millimeters	Total Depth of Decarburization Millimeters
Up to 9.52, incl	0.38
Over 9.52 to 12.70, incl	0.43
Over 12.70 to 15.88, incl	0.48
Over 15.88 to 25.40, incl	0.56
Over 25.40 to 38.10, incl	0.64
Over 38.10 to 50.80, incl	0.76
Over 50.80 to 63.50, incl	0.89
Over 63.50 to 101.60, incl	1.02

3.5.3.4 Decarburization shall be measured by the metallographic method or by a traverse method using microhardness testing in accordance with ASTM E 384. The microhardness method shall be conducted on a hardened but untempered specimen protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization, when measured by the microhardness method, is defined as the perpendicular distance from the surface to the depth under that surface where there is no further increase in hardness. Such measurements shall be far enough away from any adjacent surface to be uninfluenced by any decarburization on the adjacent surface. In case of dispute, the depth of decarburization determined using the microhardness traverse method shall govern.

3.5.3.4.1 When determining the depth of decarburization, it is permissible to disregard local areas provided the decarburization of such areas does not exceed the limits of Table 4 by more than 0.005 inch (0.13 mm) and the width is 0.065 inch (1.65 mm) or less.

3.5.4 Average Grain Size

Prior austenitic grain size shall be ASTM No. 6 or finer for product 100 square inches (645 cm²) and under in cross-sectional area, determined in accordance with ASTM E 112.

3.5.5 Response to Heat Treatment

3.5.5.1 Bars and Forgings

Test specimens cut from product 100 square inches (645 cm²) and under in cross-sectional area that have been normalized and overaged as in 3.4 shall have the properties specified in 3.5.5.1.1, 3.5.5.1.2, and 3.5.5.1.3 after being heated to 1575 °F ± 25 (857 °C ± 14), held at heat for 60 minutes ± 5, oil quenched, cooled to -100 °F ± 15 (-73 °C ± 8), held at temperature for 60 minutes ± 5, warmed in air to room temperature, and aged by heating to 950 °F ± 10 (510 °C ± 6), holding at heat for not less than five hours, and forced air cooling. The 1650 °F ± 25 (899 °C ± 14) normalized portion of the cycle applied to the test samples may be deleted if the parent product has previously been treated as in 3.3.

3.5.5.1.1 Longitudinal Tensile Properties

Shall be as shown in Table 5, determined in accordance with ASTM E 8 / E 8M; testing in the longitudinal direction need not be performed on product tested in the transverse direction.

TABLE 5 - MINIMUM LONGITUDINAL TENSILE PROPERTIES

Property	Value
Tensile Strength	235 ksi (1620 MPa)
Yield Strength at 0.2% Offset	215 ksi (1482 MPa)
Elongation in 4D	12%
Reduction of Area	60%

3.5.5.1.2 Transverse Tensile Properties

Shall be as shown in Table 6, determined on specimens selected and prepared in accordance with AMS2310; transverse tensile 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
Tensile Strength	235 ksi (1620 MPa)
Yield Strength at 0.2% Offset	215 ksi (1482 MPa)
Elongation in 4D	12%
Reduction of Area	55%

3.5.5.1.3 Fracture Toughness

Shall not be less than 130 ksi $\sqrt{\text{inch}}$ (143 Mpa $\sqrt{\text{m}}$) K_{IC} or K_Q , determined in accordance with ASTM E 399, with a B dimension of 1.50 inches (38.1 mm) or greater and W dimensions as specified. Sample orientation shall be L-S or L-T for billet, rectangular bar, or forging and L-R or L-C for round bar.

3.5.5.1.3.1 Testing smaller product not accommodated by 3.5.5.1.3 shall be conducted using Charpy V-notch test in accordance with ASTM E 23, with longitudinal axis parallel to the grain direction. The minimum impact value shall be 45 foot pounds (61 J) at room temperature.

3.5.5.2 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4 and 3.5.5.1, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.5.1.1, and/or 3.5.5.1.2, and 3.5.5.1.3. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.5.1 conform to the requirements of 3.5.5.1.1 and/or 3.5.5.1.2, and 3.5.5.1.3, tests 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 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 machined, ground, turned, or polished surface.

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 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 (3.3.1), decarburization (3.5.3) and average grain size (3.5.4) of each lot.

4.2.1.3 Tensile properties (3.5.5.1.1 and/or 3.5.5.1.2) and fracture toughness (3.5.5.1.3) of each lot of bars and forgings after heat treatment.

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 (3.5.5.2).

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

Shall be as follows:

4.3.1 Bars and Forging Stock

In accordance with AMS2370.

4.3.2 Forgings

In accordance with AMS2372.