



AEROSPACE MATERIAL SPECIFICATION

AMS5611™**REV. G**

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Superseding AMS5611F

Steel, Corrosion and Heat-Resistant, Bars, Wire, Forgings, Forging and Ring Stock,
Mechanical Tubing, and Rings
12Cr
Ferrite Controlled, Annealed, Consumable Electrode Melted
(Composition similar to UNS S41001)

RATIONALE

AMS5611G prohibits unauthorized exception (3.7, 4.4.4, 5.2.1.2, 8.8), adds types and a default type (1.3, 8.9), updates composition testing (3.1), updates bar condition (3.3.1.1, 3.3.1.2, 8.9) and forging condition (3.3.3), modifies macroetch (3.4.1), adds decarburization test method (3.4.2.1.2), prohibits bars cut from plate (3.5.4.4, 4.4.2), adds stock allowance information (3.5.2, 8.6), adds country of origin requirements (4.4.1, 4.4.3), adds requirements for reporting of forging and ring stock (4.4.3), allows prior revisions (8.7), and is the result of a Five-Year Review and update of the specification.

1. SCOPE

1.1 Form

This specification covers a premium aircraft-quality, corrosion and heat-resistant steel in the form of bars, wire, 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 uniformly high room-temperature tensile properties with oxidation resistance up to 1000 °F (538 °C), where control of delta ferrite is necessary, but usage is not limited to such applications.

1.2.1 Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking; ARP1110 recommends practices to minimize such conditions.

1.3 Classification

Steel covered by this specification is classified by melting practice as follows:

Type 1 - Multiple melted using consumable electrode vacuum arc (VAR) practice in the remelt cycle.

Type 2 - Multiple melted using electroslog (ESR) remelting in the final melting cycle.

1.3.1 When a type is not specified, Type 1 shall be supplied (see 8.9).

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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.

AMS2241	Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
AMS2243	Tolerances, Corrosion and Heat-Resistant Steel Tubing
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
AMS2315	Determination of Delta Ferrite Content
AMS2371	Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steels and Alloys, Wrought Products and Forging Stock
AMS2374	Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steel and Alloy Forgings
AMS2806	Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys
AMS2808	Identification Forgings
AMS7493	Rings, Flash Welded, Ferritic and Martensitic Corrosion-Resistant Steels
ARP1110	Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys
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

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	Chemical Analysis of Steel Products
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 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	0.12	0.15
Manganese	--	0.60
Silicon	--	0.50
Phosphorus	--	0.025
Sulfur	--	0.025
Chromium	11.50	12.50
Nickel	--	0.75
Molybdenum	--	0.20
Aluminum	--	0.05
Copper	--	0.50
Tin	--	0.05
Nitrogen	--	0.18

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248.

3.2 Melting Practice

Shall be multiple melted using vacuum consumable electrode remelting (Type 1) or electroslag remelting (Type 2) in the remelt cycle (see 1.3).

3.3 Condition

The product shall be supplied in the following condition; hardness and tensile strength shall be determined in accordance with ASTM A370:

3.3.1 Bars

Annealed having hardness not higher than 241 HB, or equivalent (see 8.2).

3.3.1.1 All hexagons, regardless of size, and other bars 2.750 inches (69.85 mm) and under in nominal diameter or least distance between parallel sides, shall be cold finished.

3.3.1.2 Bars, other than hexagons, over 2.750 inches (69.85 mm) in nominal diameter or least distance between parallel sides shall be hot finished or cold finished.

3.3.2 Wire

Cold drawn and annealed having tensile strength not higher than 115 ksi (793 MPa).

3.3.3 Forgings and Flash Welded Rings

Annealed having hardness not higher than 241 HB, or equivalent (see 8.2).

3.3.3.1 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 AMS7493.

3.3.4 Mechanical Tubing

Annealed and cold finished having hardness not higher than 241 HB, or equivalent (see 8.2).

3.3.5 Stock for Forging or Flash Welded Rings

As ordered by the forging or flash welded ring manufacturer.

3.4 Properties

The product shall conform to the following requirements; tensile and hardness testing shall be performed in accordance with ASTM A370.

3.4.1 Macrostructure

Visual examination of transverse sections from bars, wire, billets, tube rounds, and stock for forging or flash welded rings, etched in hot hydrochloric acid in accordance with ASTM A604, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections for product 36 square inches (232 cm²) and under in nominal cross-sectional area shall be no worse than the macrographs of ASTM A604 shown in Table 2. Macroetch limits for product with nominal cross-section larger than 36 square inches (232 cm²) shall be agreed upon by purchaser and producer.

Table 2 - Macrostructure limits

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

3.4.2 Bars, Wire, Tubing, and Flash Welded Rings

3.4.2.1 Decarburization

3.4.2.1.1 Bars, wire, tubing, and flash welded rings ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces.

3.4.2.1.2 Decarburization shall be evaluated by one of the methods of 3.4.2.1.2.1 or 3.4.2.1.2.2.

3.4.2.1.2.1 Metallographic Method

A cross-section taken perpendicular to the surface shall be prepared, etched, and visually examined metallographically at a magnification not to exceed 100X. Optical indications of decarburization shall not show a layer of complete (ferrite) or partial decarburization.

3.4.2.1.2.2 Hardness Traverse Method

The total depth of decarburization shall be determined by a traverse method using microindentation hardness testing in accordance with ASTM E384, conducted on a sample heat-treated in accordance with 3.4.2.2; the sample will have been protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization 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.

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

3.4.2.1.4 In the case of dispute, the total depth of decarburization determined using the microindentation hardness traverse method shall govern.

3.4.2.2 Response to Heat Treatment

Bars, wire, forgings, tubing, and flash welded rings shall have the properties shown in Table 3, determined on full-thickness specimens taken from product 0.500 inch (12.70 mm) and under in nominal diameter or distance between parallel sides, or from samples with a minimum dimension of 0.500 inch $\pm$ 0.100 inch (12.70 mm $\pm$ 2.54 mm) cut from larger product except that samples for tensile tests cut from larger product shall have a minimum dimension of 0.500 to 0.750 inch (12.70 to 19.05 mm). The specimens shall be hardened by heating to 1735 °F $\pm$ 25 °F (946 °C $\pm$ 14 °C), holding at heat for 1 hour $\pm$ 0.1 hour, and cooling in still air to room temperature and double tempered by heating to 600 °F $\pm$ 10 °F (316 °C $\pm$ 6 °C), holding at heat for 2 hours $\pm$ 0.25 hour, and cooling in air, reheating to 600 °F $\pm$ 10 °F (316 °C $\pm$ 6 °C), holding at heat for 2 hours $\pm$ 0.25 hour, and cooling in air.

3.4.2.2.1 Longitudinal Tensile Properties

Table 3 - Minimum longitudinal tensile properties

Property	Value
Tensile Strength	180 ksi (1241 MPa)
Yield Strength at 0.2% Offset	145 ksi (1000 MPa)
Elongation in 2 Inches (50 mm) or 4D	10%
Reduction of Area	30%

3.4.2.2.1.1 Long-Transverse Tests

May be used instead of longitudinal tests if obtainable from the product.

3.4.2.2.2 Hardness

Should be 39 to 44 HRC, or equivalent (see 8.2). The product shall not be rejected on the basis of hardness if the tensile properties of 3.4.2.2.1 are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.

3.4.2.2.3 Average Grain Size

Shall be 5 or finer, determined in accordance with ASTM E112 (see 8.4).

3.4.2.2.4 Delta Ferrite Content

Shall be not more than 5%, determined in accordance with AMS2315.

3.4.3 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4.2.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.2.2.1, 3.4.2.2.2, 3.4.2.2.3, and 3.4.2.2.4. If specimens taken from the stock after heat treatment as in 3.4.2.2 conform to the requirements of 3.4.2.2.1, 3.4.2.2.2, 3.4.2.2.3, and 3.4.2.2.4, the tests shall be acceptable as equivalent to tests of a forged coupon.

3.4.4 Stock for Flash Welded Rings

Specimens taken from the stock after heat treatment as in 3.4.2.2 shall conform to the requirements of 3.4.2.2.1, 3.4.2.2.2, 3.4.2.2.3, and 3.4.2.2.4.

3.5 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, consistent with the type of steel involved, and free from foreign materials and from imperfections detrimental to usage of the product.

3.5.1 Steel shall be premium aircraft-quality conforming to AMS2300.

3.5.2 Bars and mechanical tubing shall be free from seams, laps, tears, and cracks after removal of the standard stock removal allowance in accordance with AS1182. Superficial surface imperfections such as scratches or pits shall not exceed applicable tolerances.

3.5.3 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.

3.5.4 Bars shall not be cut from plate (see 4.4.2).

3.6 Tolerances

Shall be as follows:

3.6.1 Bars and Wire

In accordance with AMS2241.

3.6.2 Mechanical Tubing

In accordance with AMS2243.

3.7 Exceptions

Any exceptions shall be authorized by the purchaser and reported in 4.4.4.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer'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 (see 3.1) of each heat.

4.2.1.2 Macrostructure (see 3.4.1.) of each heat.

4.2.1.3 Decarburization (see 3.4.2.1) of each lot of bars, wire, tubing, and flash welded rings ordered ground, turned, or polished.

4.2.1.4 Longitudinal tensile properties (see 3.4.2.2.1), average grain size (see 3.4.2.2.3), and ferrite content (see 3.4.2.2.4) of each lot of bars, wire, forgings, tubing, and flash welded rings after hardening and double tempering.

4.2.1.5 Tolerances of bars and wire (see 3.6.1) and mechanical tubing (see 3.6.2).

4.2.2 Periodic Tests

Hardness (see 3.4.2.2.2) of bars, wire, forgings, tubing, and flash welded rings after heat treatment, frequency-severity cleanliness rating (see 3.5.1), grain flow of die forgings (see 3.5.3), and tests of forging stock (see 3.4.3) and of stock for flash welded rings (see 3.4.4) to demonstrate ability to develop required properties are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

Shall be as follows:

4.3.1 Bars, Wire, Mechanical Tubing, Flash Welded Rings, and Stock for Forging or Flash Welded Rings

In accordance with AMS2371.

4.3.1.1 Specimens for grain size of flash welded rings shall be cut from parent metal not including the weld-heat-affected zone.

4.3.2 Forgings

In accordance with AMS2374.

4.4 Reports

4.4.1 The producer of the mechanical tubing, forgings, bar, wire, and flash welded rings shall furnish with each shipment a report showing the producer's name and the country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations) and the results of tests for composition, macrostructure, and, when performed, frequency-severity cleanliness rating of each heat and for tensile properties, average grain size, and percent ferrite 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, AMS5611G, size, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.4.2 For bar, report the nominal metallurgically worked cross sectional size and the cut size, if different (see 3.5.4).

4.4.3 The producer of forging and ring stock shall furnish with each shipment a report showing the producer's name and the country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations) and the results of tests for composition, macrostructure, and the results of any additional property requirements imposed by 8.9. This report shall include the purchase order number, heat and lot numbers, AMS5611G, product form and size or part number, and quantity.

4.4.4 When material produced to this specification has exceptions taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS5611G(EXC) because of the following exceptions:" and the specific exceptions shall be listed (also see 5.2.1.2).

4.5 Resampling and Retesting

Shall be as follows:

4.5.1 Bars, Wire, Mechanical Tubing, Flash Welded Rings, and Stock for Forging or Flash Welded Rings

In accordance with AMS2371.

4.5.2 Forgings

In accordance with AMS2374.