



AEROSPACE MATERIAL SPECIFICATION

AMS4911

REV. N

Issued 1957-07
Revised 2014-03

Superseding AMS4911M

Titanium Alloy, Sheet, Strip, and Plate
6Al - 4V
Annealed

(Composition similar to UNS R56400)

RATIONALE

AMS4911N results from an update of this specification to restrict material to the sizes of the mechanical property tables (1.1), to require vacuum in the first consumable electrode melt (3.2) and agreement of mechanical property values on material outside specification ranges (3.5.1.3 and 8.5), and includes ultrasonic testing of all plate 0.500 inch (12.70 mm) and over (3.6.1), adds AS6279 (3.8) and revises the report paragraph (4.4).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of sheet, strip, and plate up through 4.000 inches (101.60 mm) inclusive in thickness (See 8.5).

1.2 Application

These products have been used typically for parts requiring strength up to 750 °F (399 °C), but usage is not limited to such applications.

1.2.1 Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP982 recommends practices to minimize such conditions.

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.

AMS2242 Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate

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AMS2249	Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS2631	Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet
AMS2750	Pyrometry
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products
AS6279	Industry Standard Practices 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 E 8 / E 8M	Tension Testing of Metallic Materials
ASTM E 290	Bend Testing Material for Ductility
ASTM E 384	Knoop and Vickers Hardness of Materials
ASTM E 539	Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry
ASTM E 1409	Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E 1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
ASTM E 1941	Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis
ASTM E 2371	Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1; carbon shall be determined in accordance with ASTM E 1941, hydrogen in accordance with ASTM E 1447, oxygen and nitrogen in accordance with ASTM E 1409, and other elements in accordance with ASTM E 539 or ASTM E 2371. Other analytical methods may be used if acceptable to the purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Aluminum	5.50	6.75
Vanadium	3.50	4.50
Iron	--	0.30
Oxygen	--	0.20
Carbon	--	0.08
Nitrogen	--	0.05 (500 ppm)
Hydrogen (3.1.2)	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Other Elements, each (3.1.1)	--	0.10
Other Elements, total (3.1.1)	--	0.40
Titanium	remainder	

- 3.1.1 Determination not required for routine acceptance.
- 3.1.2 Sample size, when using ASTM E 1447, may be as large as 0.35 gram.
- 3.1.3 Check Analysis

Composition variations shall meet the applicable requirements of AMS2249.

3.2 Melting Practice

Alloy shall be multiple melted. The first melt shall be made by vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The subsequent melt or melts shall be made under vacuum using vacuum arc remelting (VAR) practice. Alloy additions are not permitted in the final melt cycle.

- 3.2.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be argon and/or helium at an absolute pressure not higher than 1000 mm of mercury.
- 3.2.2 The electrode tip for nonconsumable electrode melting shall be water-cooled copper.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Sheet and Strip

Hot rolled with or without subsequent cold reduction, annealed, descaled, and leveled, having a surface appearance comparable to a commercial corrosion-resistant steel sheet No. 2D finish (See 8.2).

3.3.2 Plate

Hot rolled, annealed, descaled, and flattened, having a surface appearance comparable to a commercial corrosion-resistant steel No. 1 finish (See 8.2). Plate product shall be produced using standard industry practices for the production of plate to the procured thickness. Bar, billet, forgings, or forging stock shall not be substituted for plate.

3.4 Annealing

The product shall be annealed by heating to a temperature within the range 1300 to 1650 °F (704 to 899 °C), holding at the selected temperature within ± 25 °F (± 14 °C) for a time commensurate with product thickness and the heating equipment and procedure used, and cooling at a rate which will produce product meeting the requirements of 3.5. Pyrometry shall be in accordance with AMS2750.

3.5 Properties

The product shall conform to the following requirements and also shall meet the requirements of 3.5.1 and 3.5.2 after being reheated in air to 1325 °F \pm 15 (718 °C \pm 8), held at heat for 20 minutes \pm 2, cooled at a rate equivalent to an air cool or slower.

3.5.1 Tensile Properties

Shall be as specified in Table 2, determined in accordance with ASTM E 8 / E 8M with the rate of strain set at 0.005 inch/inch/minute (0.005 mm/mm/minute) and maintained within a tolerance of ± 0.002 inch/inch/minute (0.002 mm/mm/minute) through the 0.2% offset yield strain.

TABLE 2A - MINIMUM TENSILE PROPERTIES, INCH/POUND UNITS

Nominal Thickness, Inches			Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 inches or 4D %
Up	to 0.008,	excl	134	126	--
0.008	to 0.025,	excl	134	126	6
0.025	to 0.063,	excl	134	126	8
0.063	to 0.1875,	excl	134	126	10
0.1875	to 4.000,	incl	130	120	10

TABLE 2B - MINIMUM TENSILE PROPERTIES, SI UNITS

Nominal Thickness, Millimeters			Tensile Strength MPa	Yield Strength at 0.2% Offset, MPa	Elongation in 50.8 mm or 4D, %
Up	to 0.20,	excl	920	869	--
0.20	to 0.63,	excl	920	869	6
0.63	to 1.60,	excl	920	869	8
1.60	to 4.76,	excl	920	869	10
4.76	to 101.60,	incl	893	827	10

- 3.5.1.1 Tensile property requirements apply in both the longitudinal and long transverse directions.
- 3.5.1.2 Tests in the long transverse direction need be made only on sheet and strip product that a specimen not less than 8.0 inches (203 mm) in length can be obtained; for plate, tests in the long transverse direction need be made only on product at least 0.375 inches (9.5 mm) thick that a specimen at least 2.50 inches (63.5 mm) in length can be obtained.
- 3.5.1.3 Mechanical property requirements for product outside the range covered by Table 2 shall be agreed upon between purchaser and producer.

3.5.2 Bending

Product under 0.1875 inch (4.762 mm) in nominal thickness shall have a test sample prepared nominally 0.750 inch (19.06 mm) in width, with its axis of bending parallel to the direction of rolling. The sample shall be bend tested in conformance with the guided bend test defined in ASTM E 290 through an angle of 105 degrees. The test fixture supports shall have a contact radius 0.010 inch (0.25 mm) minimum, and the plunger shall have a radius equal to the bend factor shown in Table 3 times the nominal thickness. Examination of the bent sample shall not show evidence of cracking when examined at 15 to 25X magnification.

TABLE 3 - BENDING PARAMETERS

Nominal Thickness Inch			Nominal Thickness Millimeters		Bend Factor
Up	to 0.070,	incl	Up	to 1.78,	4.5
Over 0.070	to 0.1874,	incl	Over 1.78	to 4.76,	5
				incl	

3.5.3 Microstructure

Shall be that structure resulting from alpha-beta processing. Microstructure shall conform to 3.5.3.1, or 3.5.3.2, or 3.5.3.3, or 3.5.3.4. A microstructure showing a continuous network of alpha in prior beta grain boundaries is not acceptable.

- 3.5.3.1 Lamellar alpha with some equiaxed alpha in a transformed beta matrix.
- 3.5.3.2 Equiaxed alpha in a transformed beta matrix.
- 3.5.3.3 Equiaxed alpha and elongated alpha in a transformed beta matrix.
- 3.5.3.4 Partially broken and distorted grain boundary alpha with plate-like alpha.

3.5.4 Surface Contamination

The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined as in any one of the following: 3.5.4.1, 3.5.4.2, 3.5.4.3, or other method acceptable to purchaser.

3.5.4.1 The bend test of 3.5.2.

3.5.4.2 Microscopic examination at 400X minimum.

3.5.4.3 A surface hardness more than 40 points higher than subsurface hardness, determined in accordance with ASTM E 384 on the Knoop scale using a 200-gram load, shall be evidence of unacceptable surface contamination.

3.6 Quality

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from "oil cans" (See 8.3.1) of depth in excess of the flatness tolerances, ripples, and foreign materials and from imperfections detrimental to usage of the product.

3.6.1 Plate 0.500 inches (12.70 mm) and over in nominal thickness shall be ultrasonically inspected in accordance with AMS2631 and shall meet Class A1 requirements of that document.

3.7 Tolerances

Shall conform to all applicable requirements of AMS2242.

3.7.1 Special flatness may be specified for plate; in which case, the special flatness tolerances of AMS2242 apply.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279. This requirement becomes effective October 1, 2015.

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

4.2.1.1 Composition (3.1), condition (3.3), tensile properties (3.5.1), bending (3.5.2), microstructure (3.5.3), surface contamination (3.5.4), and tolerances (3.7) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.1.2 When required, ultrasonic quality (3.6.1) of each plate,

4.2.2 Periodic Tests

Tests of the product after reheating as in 3.5 for tensile properties (3.5.1) and bending properties (3.5.2) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

Shall be in accordance with the following; a lot shall be all product of the same nominal size from the same heat processed at the same time:

4.3.1 For Acceptance Tests

4.3.1.1 Composition

One sample from each heat, except that for hydrogen determinations one sample from each lot obtained after thermal and chemical processing is completed.

4.3.1.2 Tensile Properties, Bending, Microstructure, and Surface Contamination

One or more samples from each lot.

4.3.1.3 Ultrasonic Quality

Each plate, when required by 3.6.1.

4.4 Reports

4.4.1 The producer shall furnish with each shipment a report showing producer identity and country where the metal was melted (i.e., final melt in the case of metal processed by multiple melting operations) and the results of tests for composition of each heat and for hydrogen content, tensile properties, bending, and surface contamination of each lot, and ultrasonic inspection of each plate, when required, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS4911N, product form, size, specific annealing treatment used, and quantity.

4.4.2 When the product size is outside the range covered by Table 2, the report shall contain a statement to that effect.

4.5 Resampling and Retesting

If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY

5.1 Identification

In accordance with AMS2809.

5.2 Packaging

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

A vendor shall include this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Product not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

8.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

- 8.2 Commercial corrosion-resistant steel finishes are defined in ASTM A 480/A 480M and AS4194.
- 8.3 Terms used in AMS are clarified in ARP1917 and as follows:
- 8.3.1 "Oil Can" is defined as an excess of material in a localized area of a sheet that causes the sheet to buckle in that area. When the sheet is placed on a flat surface and hand pressure applied to the buckle, the buckle will spring through to the opposite surface or spring up in another area of the sheet.
- 8.4 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.
- 8.5 Purchase documents should specify not less than the following:

AMS4911N

Product form and size of product desired

Quantity of product desired

Property and acceptance requirements from the cognizant engineering organization applicable to sizes outside the size range listed in 1.1.

PREPARED BY AMS COMMITTEE "G"