



# AEROSPACE MATERIAL SPECIFICATION

AMS4911™

REV. P

Issued 1957-07  
Revised 2018-02  
Superseding AMS4911N

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

(Composition similar to UNS R56400)

## RATIONALE

AMS4911P results from a Five-Year Review and update of this specification that includes the addition of ASTM E2994 (3.1), removal of sample size allowance for hydrogen of Table 1 (covered by ASTM E1447), addition of AMS2368 for Sampling and Resampling (4.3 and 4.5) and revises reporting and marking (4.4 and 5.1).

### 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.

#### 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 +1 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

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

AMS2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys

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on this Technical Report, please visit  
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AMS2368	Sampling and Testing of Wrought Titanium Raw Material Except Forgings and Forging Stock
AMS2631	Ultrasonic Inspection Titanium and Titanium Alloy Bar, Billet and Plate
AMS2750	Pyrometry
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications
AS1814	Terminology for Titanium Microstructures
AS4194	Sheet and Strip Surface Finish Nomenclature
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](http://www.astm.org).

ASTM A480/A480M	General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip
ASTM E8/E8M	Tension Testing of Metallic Materials
ASTM E290	Bend Testing Material for Ductility
ASTM E384	Microindentation Hardness of Materials
ASTM E539	Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry
ASTM E1409	Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion
ASTM E1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
ASTM E1941	Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis
ASTM E2371	Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry
ASTM E2994	Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge 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 E1941, hydrogen in accordance with ASTM E1447, oxygen and nitrogen in accordance with ASTM E1409, and other elements in accordance with ASTM E539, ASTM E2371 or ASTM E2994. 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	--	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 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 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  $\pm 25$  °F ( $\pm 14$  °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 ± 15 °F (718 °C ± 8 °C), held at heat for 20 minutes ± 2 minutes, 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 E8/E8M 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 2**

**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 1.1 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 E290 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	Over 0.070 to 0.1874, incl	Up to 1.78, incl	Over 1.78 to 4.76, incl	4.5
				5

### 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 Examination of a metallographic cross section at 400X minimum magnification.

3.5.4.3 A surface hardness more than 40 points higher than subsurface hardness, determined in accordance with ASTM E384 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 8.4.1) 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.

## 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

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 producer unless frequency of testing is specified by purchaser.

### 4.3 Sampling and Testing

Shall be in accordance with AMS2368 and 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, country where the metal was melted (i.e., final melt in the case of metal processed by multiple melting operations), 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, AMS4911P, product form, size, specific annealing treatment used, and quantity.

4.4.2 When material produced to this specification is beyond the sizes allowed in the scope or tables, or other exceptions are taken to the technical requirements listed in Section 3, (see 5.1.1) the report shall contain a statement "This material is certified as AMS4911P(EXC) because of the following exceptions:" and the specific exceptions shall be listed.

#### 4.5 Resampling and Retesting

Shall be in accordance with AMS2368.

### 5. PREPARATION FOR DELIVERY

#### 5.1 Identification

In accordance with AMS2809.

5.1.1 When technical exceptions are taken (see 4.4.2), the material shall be marked with AMS4911P(EXC).

#### 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 producer 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 Revision Indicator

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 A480/A480M and AS4194.

8.3 Terminology relating to titanium microstructures is presented in AS1814.

8.4 Terms used in AMS are clarified in ARP1917 and as follows:

8.4.1 "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.

8.5 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.

8.6 Purchase documents should specify not less than the following:

AMS4911P

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"